चन्द्रच्छायागणितम्

COMPUTATIONS CONCERNING MOON'S SHADOW

OF

NĪLAKAṆṬHA SOMAYĀJĪ

Edited by

K. V. SARMA

HOSHIARPUR

VISHVESHVARANAND VISHVA BANDHU INSTITUTE
OF SANSKRIT AND INDOLOGICAL STUDIES
PANJAB UNIVERSITY

Panjab University Indological Series—6

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पञ्जाब-विश्वविद्यालयीय-भारती-शोधग्रन्थमाला—६

प्रधान-सम्पादकः—के. वी. शर्मा

General Editor—K. V. SARMA

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Critically edited with
Introduction, Translation and Appendices

By

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HOSHIARPUR
1976

प्रथमं संस्करणम्, २०३३ (वि.)

प्रकाशकृत्

विश्वेश्वरानन्द-विश्ववन्धु-संस्कृत-
भारती-शोध-संस्थानम्

पञ्जाब-विश्वविद्यालयः

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INTRODUCTION

Chāyāgaṇita in Hindu Astronomy

The *Candracchāyāgaṇita* edited here critically for the first time, from original manuscripts, with Translation and auto-commentary, is an interesting astronomical manual by Nīlakaṇṭha Somayājī, a reputed mediaeval astronomer of Kerala (*c.* 1443-1545 A.D.).

Chāyāgaṇita or 'Computations concerning the Shadow' constitutes the Hindu astronomer's method for ascertaining the exact time of occurrence of any event on the basis of the shadow cast by the Sun or the Moon. The expediency of this device during ancient and mediaeval times would be apparent when one considers the limitations of such chronometrical devices as the hour-glass, water-disc, etc. The gnomon, being one of the simplest of astronomical instruments that could be set up at any time and at any place, and readings made independent of circumscribing factors like zero-point etc., is the most handy instrument to record such abrupt occurrences as the birth of a child, death of a person and setting in of the initial menstruum. A knowledge of the exact moment of these happenings, as computed by astronomical methods from the measure of the shadow, facilitates the prediction of the future based on them in accordance with the dictums of astrology. Obviously, the shadow cast by the Sun is measured during day and that by the Moon during night.

Kramacchāyā and Viparītacchāyā

The utility *Chāyāgaṇita* in the daily life of the mediaeval Hindu, whose prescribed way of life required the performance of numerous religious rites, is not far to seek. Ordinary astronomical computation enabled him to calculate auspicious times (*muhūrta*) for sacred rites and social functions, in terms of time-units like *nāḍikās* and *vināḍikās*, say, after sunrise or sunset. But, in the absence of accurate chronometers, it was not easy to ascertain when that auspicious moment, as calculated, had arrived. *Chāyāgaṇita* came to his rescue in such a situation. For, it was possible to calculate, in advance, the length that the Sun's or the Moon's shadow would attain at the appointed time. One could, then,

set up the gnomon and watch for the shadow to reach the stipulated length and perform the rite at the right moment. This process of computing the shadow for any specific Time is called *Krama-cchāyā*, 'Direct (process of) Shadow (computation)'.

The corollary of *Kramacchāyā*, known as *Viparīta-cchāyā*, 'Reverse (process of) Shadow (computation)', according to which Time is calculated from the length of the Shadow, was, equally, if not more, important in everyday life, in that it enabled the accurate ascertainment of the time of abrupt, nonplanned occurrences like moments of birth and death, unexpected arrivals, untoward happenings and the like.

Popularity of Chāyāgaṇita in Kerala

The mediaeval astronomers of Kerala seem to have taken the best advantage of this natural phenomenon and devised highly intricate calculations to get the exact times corresponding to the measures of the shadow, taking into consideration also the factors that affected the shadow, such as the latitude and longitude of the place, time of the year, precession of the equinoxes, etc. Practically every one of the numerous astronomical manuals (*Karaṇa-granthas*) produced in Kerala contain sections devoted to *Chāyāgaṇita*, both of the Sun and of the Moon. In the *Pañcabodha* manuals, of which about a dozen different texts have been identified and documented, *Chāyā* is one of the five subjects dealt with, the others being *Vyatīpāta*, *Grahaṇa*, *Śṛṅgonnati* and *Mauḍhya*.[1] Several texts which are devoted solely to computations based on shadow have also come to be composed.[2]

Candracchāyāgaṇita

What is more interesting, computations concerning the Moon's shadow being more important, several manuals exclusively devoted to *Candracchāyā* have also come to be composed, though the calculations

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1. See K.V. Sarma, *History of the Kerala School of Hindu Astronomy*, (Hoshiarpur, 1972), Sn. on 'Bibliography of Kerala Jyotiṣa', pp. 134-37.

2. See, for instance, *Chāyāgaṇanāṣṭaka*, *Chāyāgaṇita*, I-II, *Chāyāṣṭaka* of Acyuta Piṣāraṭi (*op.cit.*, p. 118), *Sūryacandracchāyāgaṇita* (p. 176), *Sūryacchāyādigaṇita*, I-II (p. 177).

here are more involved and intricate. These include five different works, all entitled *Candracchāyāgaṇita,* and *Candracchāyānayanopāyaḥ.*[1]

The *Candracchāyāgaṇita* of Nīlakaṇṭha Somayājī, belongs to this genre of texts and sets out the processes for the computation both of *Kramacchāyā,* 'Shadow from Time' (verses 1-17), and *Viparītacchāyā,* 'Time from Shadow' (verses 18-32), of the Moon. The commentary by Nīlakaṇṭha himself gives a lucid exposition of the textual verses. The Translation in English, with footnotes wherever needed, as presented on pages facing the text, is intended to set out the sense of the textual verses in terms of modern mathematics, reserving a full-fledged demonstration thereof for being presented elsewhere on another occasion.

Nilakaṇṭha's authorship of the work

The *Candracchāyāgaṇita* carries no benedictory verse but commences abruptly with the subject-matter. No indication, therefore, is available in the beginning of the work either about the author or the title of the work. The authorship is, however, ascertained from the concluding verse of the work which reads as follows (p. 25) :

नीलकण्ठोद्धृतो जातस्तन्त्राब्धेर्न्यायदीधितिः ।
जयत्युद्योतयन् कृत्स्नं प्रभागणितचन्द्रमाः ॥ ३२ ॥

'Victorious shines, illuminating everything, the 'Moon of Shadow-computation', with its brilliant rays of rules, having been extracted by Nīlakaṇṭha (Somayājī) from the ocean of astronomical lore.'

The commentary, however, carries an introductory verse which specifies the title of the work and also indicates that the author himself composed the commentary (p. 2, below) :

जन्मस्थितिहृतयः स्युर्जगतो यस्मात् प्रणम्य तद्ब्रह्म ।
चन्द्रच्छायागणितं कर्त्रा व्याख्यायतेऽस्य गार्ग्येण ॥

'Having paid obeisance to that Brahman, whence (take place) the origin, subsistence and extinction of the worlds, (the work) *Candracchāyāgaṇita* is being commented upon by its author himself, *viz.*, Gārgya (Kerala-Nīlakaṇṭha Somayājī).'

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1. *Op. cit.*, pp. 115-16.

Manuscript material

The present edition of *Candracchāyāgaṇita* and its auto-commentary is based on the only three manuscripts of the text and one manuscript of the commentary thus far identified, all of them being preserved in the Oriental Research Institute and Manuscripts Library of the Kerala University, Trivandrum.

A. Ms. No. 5862-B, a well-preserved palmleaf manuscript in Malayalam script procured from Shri Tuppan Nampūtiri of the Ponnorkkoṭṭu Mana, an old family of traditional scholars of Central Kerala. It contains both the text and the commentary. The manuscript is inked and the writing is very readable. However, it is not dated nor is any mention made of the scribe. The codex[1] contains the following three works, all on astronomy : *Laghukālārpaṇam*, an anonymous *karaṇa* work, *Candracchāyāgaṇita*, with auto-commentary, being the work edited here, and *Uparāgakriyākrama*, an anonymous work on the computation of eclipses according to procedures enunciated by Nīlakaṇṭha (Somayājī), as stated in its opening verse :

पुष्पवन्तौ नमस्कृत्य नीलकण्ठोक्तवर्त्मना ।
अन्यो विलिख्यते कश्चिद् उपरागक्रियाक्रमः ॥

B. Uncatalogued folios 173-77 of Ms. No. 5877, being a codex of astronomical works including Nīlakaṇṭha Somayājī's *Golasāra* and *Siddhāntadarpaṇa*. The manuscript is well preserved, but it is not dated nor any mention of the scribe made. The text alone of *Candracchāyāgaṇita* is contained herein.

C. Ms. No. 475-I, occurring in a codex of astronomical works procured from Nāreri Mana (Kūṭallūr Mana), a reputed scholarly family of Nampūtiri brāhmans in Central Kerala. The manuscript is old, brittle and frayed at the edges. It is inked and the writing is very legible, though not attractive. It contains only the textual verses which, however, are accurately inscribed. The works contained in the codex are : A. *Āryabhaṭīyam*, B. *Mahābhāskarīyam*, C. *Laghubhāskarīyam*, D. *Siddhāntadarpaṇam*, E. *Tantrasaṅgraha*, F. *Līlāvatī*, G. *Pañcabodha*, H. *Laghumānasa*, I. *Candracchāyāgaṇita*, J. *Goladīpikā*, and K. *Grahaṇāṣṭaka*.

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1. A transcript of this codex is available also in the Govt. Or. Mss. Library, Madras, No. 5185 a,b,c.

The codex can be dated by the chronogram *sevyo dugdhābdhitalpaḥ, viz.,* the 1699847th day of the Kali era, given as the date of transcription of one of the works contained herein. This date works out to A.D. 1551, being almost contemporaneous with the author Nīlakaṇṭha Somayājī who passed away in about 1545 A.D.

Assessment of the manuscripts

The tendency found in technical manuscripts to go corrupt and the ease with which errors find their way into them have not seriously affected the manuscripts used in the present edition. In fact, the text and the commentary as preserved in our manuscripts are mostly accurate and free from errors. The variants are few and just one or two alternate readings are indicated. Possibly, these emendations go back to the author himself.

The lone manuscript of the commentary does not carry the concluding verse and its exposition. Since the manuscript does not indicate any break here, it is likely that this verse, which does not contain any technical matter, has not been commented upon by the author.

Appendices

Ms. No. 5862-B contains, in continuation of the commentary, an expanded version of verses 28 and 29, in three verses with an additional correction. After this is found directions, in the Malayalam language, for a geometrical demonstration of verse 19, *paramāpakramakoṭyā* etc. Since these two fragments are related to *Candracchāyāgaṇita* edited here, they have been added as Appendices I and II, towards the end of this publication.

Nīlakaṇṭha, the author

Our author is generally referred to with the title *Somayājī*, *Somasut*, *Somasutvan* or *Comātiri*, the last being the Malayalam derivative of the Sanskrit word. A detailed colophon occurring at the end of his *Bhāṣya* on the *Gaṇitapāda* of the *Āryabhaṭīya* contains a good deal of information about him : इति श्री-कुण्डग्रामजेन गार्ग्यगोत्रेण आश्वलायनेन भाट्टेन केरलसद्ग्राम-गृहस्थेन श्री-श्वेतारण्यनाथ-परमेश्वरकरुणाधिकरणभूतविग्रहेण जातवेदः-पुत्रेण शङ्कराग्रजेन जातवेदोमातुलेन दृग्गणितनिर्मापकपरमेश्वरपुत्र-श्री-दामोदरात्तज्योतिषामयनेन रवित आत्तवेदान्तशास्त्रेण सुब्रह्मण्यसहृदयेन नीलकण्ठेन सोमसुता विरचितविविध-

ग्रन्थेन दृष्टबहूपपत्तिना स्थापितपरमार्थेन कालेन शङ्कराद्य(? य) निर्मिते श्रीमदार्यभट-सिद्धान्तव्याख्याने महाभाष्ये etc.[1]

Personal details

The above-quoted passage informs that Nīlakaṇṭha belonged to the Gārgya gotra,[2] was a follower of the *Āśvalāyana-sūtra* of the *Ṛgveda* and was a *Bhāṭṭa*. He was the son of Jātavedas and had a younger brother named Śaṅkara. He had an uncle Jātavedas by name and a close friend Subrahmaṇya. He was a performer of the *Soma* sacrifice. He had composed several works on astronomy, in which subject he had made deep and extensive investigations, a fact which is well borne out by his available works.

Some more personal details about Nīlakaṇṭha seem to be forthcoming from a Malayalam work *Laghurāmāyaṇa*.[3] This work describes itself as a work of Rāma, son of Nīlakaṇṭha of the Gārgya-gotra and resident of Kuṇḍagrāma. *Cf.* the colophon at its end : इति कुण्डग्रामजेन गार्ग्यकुलतिलकेन श्री-नीलकण्ठात्मजेन आर्याम्बा-गर्भसम्भवेन मन्वादिस्मृतिमर्मज्ञ-संस्कृत-द्राविड-भाषा-त्रय-पारीणस्य दक्षिणामूर्तिनाम्नोऽग्रजेन रामेण विरचितं श्रीरामायणं प्रबन्धम् ।

This Nīlakaṇṭha is identified by the editor of the work with our author.[4] If this identification is correct, Nīlakaṇṭha's wife was named Āryā, and he had two sons Rāma and Dakṣiṇāmūrti, the latter of whom was well versed in the Dharmaśāstras and learned in the three languages, Sanskrit, Tamil and Malayalam. The great Malayalam poet Tuñcattu

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1. Ed., *Trivandrum Sanskrit Series (TSS)*, No. 101, (Trivandrum, 1930), p. 180.

2. Generally the term *Gārgya* is affixed to his name in references. It may also be noted that in the commentary edited here, he refers to himself merely as 'Gārgya', (*cf. Candracchāyāgaṇitam vyākhyāyate'sya Gārgyeṇa*, p. 2), obviously, on account of his full name not being amenable for insertion in the verse.

3. Ed. P. R. Menon, *Tuñchattu Granthāvali*, No. 3, Tunchattu Karyalayam, Chittoor, 2nd edn., 1931.

4. *Vide* P.R. Menon in his article 'Tunchattu Ezhuttacchan' in the Malayalam monthly *Tunchattu Ezhuttacchan*, 3 (1952-53) 127-35.

Ezhuttacchan is said to have been a student of Nīlakaṇṭha. Nīlakaṇṭha is also said to have composed, at the request of a friend, a panegyric in Malayalam on the Goddess Pārvatī, the presiding deity of the temple of Ūrakam in Cochin, in order to ward off the predicted premature death of that friend's daughter.[1] The authenticity of the above work and the source of the information are, however, not quite certain, and corroborative evidences have to be found before accepting the above statements.

Birth-place and Family

Nīlakaṇṭha hailed from Tṛ-k-kaṇṭiy-ūr (Sanskritised into Śrī-Kuṇḍa-pura or Śrī-Kuṇḍa-grāma), near Tirur, S. Rly., Ponnani taluk, South Malabar, a famous seat of learning in Kerala during the middle ages. The name of his *Illam*, as the house of a Nampūtiri brāhman is called, was *Keḷallūr* (sometimes spelt also as *Kerallūr* and *Keḷannūr*), Sanskritised into *Keraḷa-sad-grāma* corresponding to the Malayalam word Keraḷa-nall-ūr.[2] Nīlakaṇṭha's house is identified as the present Eṭamana Illam, situated a little to the south of the local temple.[3] It is stated that Nīlakaṇṭha's family became extinct and the family property was inherited by the nearest *dāyādi* relations, *viz.*, the Eṭamana family.[4]

Nīlakaṇṭha's favourite deity was Lord Śiva installed at the famous temple at Tṛpparaṅṅoḍ (Sanskrit Śvetāraṇya) near his village ; *cf.*, श्री-श्वेतारण्यनाथ-परमेश्वर-करुणाभूतविग्रहेण, in the colophon to the *ĀBh.Bhāṣya* quoted above (p. xi).

Śaṅkara, the brother, and Netranārāyaṇa, the patron

Nīlakaṇṭha refers to his younger brother Śaṅkara in several places in the *ĀBh.Bhāṣya*. Śaṅkara too seems to have been well versed

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1. *Ibid.*. This stotra is published in a collection of stotras in Malayalam script, *Stavaratnamālā*, Pt. I.

2. It may be noted that in the expression *Gārgya-Kerala* prefixed to the author's name, the word *Kerala* refers to the name of his house and not to his state, as is sometimes taken.

3. *Cf.*, Vatakkumkur Rajaraja Varma, *History of Skt. Lit. in Kerala*, vol. I, p. 384.

4. I am thankful for this information to the late Sri Rama Varma Maru Thampuran, Chalakkudi (Cochin).

in astronomy and followed his elder brother's studies. Thus, after describing some methods on the Rule of three (*Trairāśika*) in his *ĀBh.Bhāṣya, Gaṇita.*, 26, Nīlakaṇṭha says how his brother who was teaching at the house of his patron explained to the latter some of those theories ; *cf.*, अत्र केषांचिद् युक्तयः पुनः अस्मदनुजेन शङ्कराख्येन तत्समीपे अध्यापयता वर्तमानेन तस्मै प्रतिपादिताः । (*TSS* 101, p. 156)

Nīlakaṇṭha observes at the close of the *Bhāṣya* on the *Golapāda* that he was entrusting the *Bhāṣya* to Śaṅkara for its proper propagation. Thus, just before the final colophon, Nīlakaṇṭha says : एवमिदम् अस्माभिर्यथामति व्याख्यातम् ।

नमः स्वयम्भुवे तस्मै यत्प्रसादादिदं कृतम् ।
नमो भगवते तस्मै श्रीमदार्यभटाय च ।।
शिष्यं तत्त्वेन विचार्यार्यभटसूत्रभाष्यमिदम् ।
यदि स न्यायाल्लिप्सेदस्मै दातव्यमेव शङ्कर ते ।।

इति गोलपादव्याख्यानं समाप्तम् ।।

(*TSS* 185, p. 164)

That Nīlakaṇṭha was intimately connected to and was patronised by Kauṣītaki Āḍhya Netranārāyaṇa, known locally as Āzhvāñceri Tamprākkal, the religious head of the Nampūtiri brāhmans of Kerala, is known from several references in his writings. It is also clear that the patron had great esteem for Nīlakaṇṭha's erudition in astronomy, in which subject he too was interested and used to discuss difficult points with Nīlakaṇṭha. Thus, in the discussion on the calculation of the motion of planets (*ĀBh., Kāla.*, 22-25), Nīlakaṇṭha says :

कर्णभुक्तिः स्फुटेत्यत्र व्याख्याने पारमेश्वरे ।
व्यासार्धाप्तं कोटिवर्गात् कर्ण्येणादावृणं धनम् ।।
कोटचां तद्वनयुग् व्यासदलं गतिविधौ श्रुतिः ।
प्रकारान्तरमाहैवं सूक्ष्मभुक्तिप्रसिद्धये ।।
गुरूणां मे पितात्रापि स्थौल्यान्मत्सरिणोदिते ।
परमेश्वर-तच्छिष्या नैव वेलागतिं विदुः ।।
इति कौषीतकी श्रुत्वा नेत्रनारायणः प्रभुः ।
मह्यं न्यवेदयत् तस्मै तदेवं प्रत्यपादयम् ।।

(*TSS* 110, p. 63)

Again, in the long discussion on the calculation of the apparent position of celestial bodies (*ĀBh.*, *Kāla.*, 17-21), speaking on a method to derive the *sakṛt-karṇa*, our author says : अन्यदपि कर्म अस्माभिरुपन्यस्यमानं श्रुत्वा ग्राढ्येन कौषीतकिना अनुष्टुभा निबद्धम् —

स्वोच्चोनमध्यमार्कस्य भुजाज्याघ्ना त्रिजीविका ।
स्वोच्चहीनस्फुटार्कस्य दोर्ज्याभुक्ता श्रुतिर्भवेत् ।। इति ।।
(*TSS* 110, p. 47)

This would indicate the intimacy that existed between Nīlakaṇṭha and his patron and the common interest that bound them together. On the compilation of the *ĀBh.Bhaṣya*, Nīlakaṇṭha observes in one place : यन्मयात्र केषांचित् सूत्राणां तद्युक्तीः प्रतिपाद्य कौषीतकिना ग्राढ्येन नारायणाख्येन व्याख्यानं कारितम्, अतस्तदेवात्र लिख्यते । (*TSS* 101, p. 113). Again, at another context, he remarks : इतीदं प्रथमे वयस्येव वर्तमानेन मया द्वितीयवयसि स्थितेन कौषीतकिना ग्राढ्येन कारितम् । ……… तस्मिन् स्वर्गते पुनः …… व्याख्यानमारब्धम् । (*TSS* 101, p. 156).

It is clear from the above that the credit of enthusing Nīlakaṇṭha in his investigations, and, in fact, to have prompted him to write his *ĀBh.Bhāṣ*ya, goes to Netranārāyaṇa,[1] the members of whose family are known all through the annals of Kerala history to have been good scholars and, at the same time, patrons of scholarship.

Ravi and Dāmodara, the Teachers

Nīlakaṇṭha informs us in his *ĀBh.Bhāṣya* that he studied Vedānta under Ravi, *cf. Ravita.ātta-Vedānta-śāstreṇa*, (*TSS* 101, p. 180). That Ravi was well versed also in jyotiśśāstra and that Nīlakaṇṭha imbibed some of his knowledge in astronomy from Ravi is clear from the introductory verse to Nīlakaṇṭha's *Siddhāntadarpaṇa*, where Ravi, his teacher, has been mentioned by *double entendre* :

श्रीमद्दामोदरं नत्वा भगवन्तं रविं तथा ।
यत्प्रसादान्मया लब्धं ज्योतिश्चरितमुच्यते ।।

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1. Even with regard to Nīlakaṇṭha's *Tantrasaṅgraha*, its introductory verse,

हे विष्णो निहितं कृत्स्नं जगत् त्वय्येव कारणे ।
ज्योतिषां ज्योतिषे तस्मै नमो नारायणाय ते ।।

has a veiled reference to his patron (Netra)-Nārāyaṇa at whose instance that work too seems to have been written.

A work on astrology, *Ācāradīpikā*, which is a detailed commentary, in verse, on *Muhūrtāṣṭaka* is ascribed to this Ravi.[1]

The teacher of Nīlakaṇṭha who actually initiated him into the science of astronomy and instructed him on the various principles underlying mathematical calculations was Dāmodara, son of the Kerala-*Dṛgganita* author Parameśvara,[2] of the Bhārgavagotra and resident of the village of Ālattūr (Sanskritised into Aśvatthagrāma) which was situated quite near Nīlakaṇṭha's own village. In his *ĀBh.Bhāṣya*, as also in his other works, Nīlakaṇṭha reverentially refers to his teacher and his studies under him. He speaks of how even as a boy he stayed with his *guru* at the latter's residence prosecuting his studies; *cf.* मया गुरुकुले वसता बाल्य एव etc. (*ĀBh.Bhāṣya, TSS* 110, p. 48). He also refers, often, to his teacher's views and quotes him ; *cf.* प्रकारान्तरेण 'चन्द्रबाहुफलवर्गे'त्यादिना श्रीमद्-दामोदराह्वयाद् गुरुमुखोद्गतेन श्लोकेनोक्ता तद्युक्ति : etc. (N's *Grahaṇa-grantha*[3] in the Trivandrum Palace Collection, Ms. No 975 ; transcript with me, p. 61); तच्चोक्तमस्मदाचार्यैः (*ĀBh.Bhāṣya, TSS* 101, p. 47); निबद्धं च तत् तदैव अस्मद्गुरुभिः पञ्चभिरुपजातिभिः 'अर्कस्फुटेनानयनं प्रकुर्यात्' etc." (*ibid*., p. 48); तदपि –

"सर्वत्र विष्कम्भदलं श्रुतौ वा व्यासार्धके स्याद् विपरीतकर्णः ।"

इत्यस्मद्गुरुणोक्तम् (*Siddhāntadarpaṇa-vyākhyā*, on verse 27, Ms. Trivandrum Palace Collection, No. 975 ; transcript with me, p. 30).

Similar quotations and other references, which Nīlakaṇṭha and later authors make, proclaim Dāmodara not only to be a prominent astronomer of the times but also as the author of erudite works on the subject, manuscripts of which, are yet to come to light.

Nīlakaṇṭha followed in the footsteps of Parameśvara, founder of the *Dṛggaṇita* system of astronomy in Kerala and one of the foremost astronomers of the land. For him Parameśvara was not only the revered father of his *Guru* but was also his *Parama-Ācarya*, by which term he generally refers to him in his works; *cf.*, यतो भार्गव-

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1. Ulloor, *Kerala Sāhitya Caritram*, vol. II, p. 114. For a Ms. of this work, see Kerala Uni. Mss. Lib., No. 3336-B.

2. *Cf.* the detailed colophon quoted above, pp. xi-xii.

3. On this work, see below, p. xx.

परमेश्वराचार्येण अस्मत्परमगुरुणा 'चलांशास्त्वं' (4546) इति कल्यब्दे परीक्ष्य पञ्चदशांशपूर्तिर्निर्णीता । etc. (*Siddhāntadarpaṇa-vyākhyā*, verse 18) ; अस्मत्परमगुरुणापि सिद्धान्तदीपिकायाम् एतत् प्रतिपादितम् । (*ĀBh. Bhāṣya, Golapāda*, verse 3).

Works of Nīlakaṇṭha

Nīlakaṇṭha has written several works which reflect his deep study of and ripe scholarship in astronomy, embodying the results of his investigations in the subject and interpreting the science lucidly. A mention of his works may, advantageously, be made here :

1. *Golasāra*[1] ('Quintessence of Spherical astronomy)' in three *paricchedas*, embodying the basic astronomical elements and procedures.

2. *Siddhāntadarpaṇa*,[2] a short work in thirty-two *anuṣṭubhs*, enunciating the astronomical constants with reference to the *Kalpa* and specifying his views on the main astronomical concepts and topics on which there is difference of opinion among authorities.

3. *Candracchāyāgaṇita*, or merely *Chāyāgaṇita*, under which title it is sometimes cited, a short work in thirty-two verses on the methods for the calculation of time from the measurement of the shadow cast by the Moon and vice-versa, being the work edited here.

4. A commentary on the *Candracchāyāgaṇita*, included in the present edition.

5. *Tantrasaṅgraha*[3] divided into eight chapters comprising 432 verses. This is a major work of Nīlakaṇṭha and is an erudite

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1. Cr. edn. with Translation, by K.V. Sarma, V.V.R. Institute, Hoshiarpur, 1970.

2. Critically Ed. with Translation by K.V. Sarma, Adyar, Library, Madras, 1955. Two short anonymous tracts, entitled *Siddhāntadarpaṇasiddha-paryayādayaḥ* and *Siddhāntadarpaṇastha-paryaya-bhūdināni*, added as Appendices to this edition, vouch for the popularity of this text.

3. Ed. with the commentary *Laghuvivṛti* by Śaṅkara, in *TSS* 188 (1958).

treatise on astronomy. As a work belonging to the *Tantra* class, it takes the commencement of the *Yuga* as the starting point for calculations. In the several chapters, it deals with : I. Astronomical constants and general principles and conceptions. II. Geocentric positions of the planets. III. The Sun's shadow. IV. Eclipses of the Moon and the Sun. V. Specialities in the Sun's eclipse. VI. *Vyatīpāta*. VII. The Phases of the Moon, etc. VIII. *Śṛṅgonnati* of the Moon.

6. *Āryabhaṭīya-Bhāṣya*,[1] an elaborate commentary on the cryptic and *sūtra*-like text of Āryabhaṭa which comprehends in 121 *āryās* the fields of Mathematics and Astronomy. A perusal of the commentary will amply prove that it is no false claim that Nīlakaṇṭha makes when he designates his work as a '*mahābhāṣya*' and explains the method of exposition adopted by him : श्रीमदार्यभटाचार्यविरचितसिद्धान्त-व्याख्याने 'महाभाष्ये' उत्तरभागे युक्तिप्रतिपादनपरे त्यक्तान्यथाप्रतिपत्तौ निरस्तदुर्व्याख्याप्रपञ्चे समुद्घाटितगूढार्थे सकलजनपदजातमनुजहिते निर्दशितगीतिपादार्थे सर्वज्योतिषामयन-रहस्यार्थनिदर्शके समुदाहृत-माधवादि गणितज्ञाचार्यकृत-युक्तिसमुदाये निरस्ताखिलविप्रति-पत्तिप्रपञ्च-समुपजनितसर्वज्योतिषामयनविदमलहृदयसरसिजविकासे निर्मले गम्भीरे अन्यूना-तिरिक्ते गणितपाद-गतार्यात्रयस्त्रिशद्व्याख्यानं समाप्तम् (*TSS* 101, p. 180).

In another context, recalling how he came to write the commentary, Nīlakaṇṭha remarks : मयाद्य प्रवयसा ज्ञाता युक्तीः प्रतिपादयितुं भास्करादिभिरन्यथाव्याख्यातानां कर्माण्यपि प्रतिपादयितुं यथाकथंचिदेव व्याख्यानमारब्धम् ॥ (*TSS* 101, p. 156).

The lucid manner in which the difficult conceptions about the celestial globe and astronomical calculations are made clear, the wealth of quotations, and the results of personal investigations and comparative studies presented herein amply justify the appellation '*Mahābhāṣya*' which Nīlakaṇṭha has given to his work.

Nīlakaṇṭha has commented only on the *Gaṇita*, *Kālakriya* and *Gola pādas* of the *Āryabhaṭīya*, leaving out the *Gītikāpāda*, which he says is covered by the commentary on the other three sections; *cf.* तत्रेयं त्रिपाद्यस्माभिर्व्याचिख्यासिता, यतस्तद्व्याख्येयरूपत्वाद् गीतिकापादस्य एतद्व्याख्यानेनैवार्थः प्रकाशेत । (*TSS* 101, p. 1).

7. *Siddhāntadarpaṇa-vyākhyā*, a commentary on his own *Siddhāntadarpaṇa*, of which an incomplete Ms. is available in the Palace Library Collection, Trivandrum, No. 975. The commentary is elaborate

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1. Ed. in *TSS* 101, 110, 185 (1930, 1931, 1957).

and resembles, in diction and treatment, his *Āryabhaṭīya-bhāṣya.* It is in this work that Nīlakaṇṭha gives the actual date of his birth (see below, p. xxiii).

8. *Grahaṇanirṇaya*, a work on the computation of lunar and solar eclipses. Manuscripts of this work are yet to be discovered, but later authors and Nīlakaṇṭha himself in his *ĀBh.Bhāṣya* quote from this work; *cf.* तदैव ग्रहणमध्यं च । स्फुटसाम्ये तु विक्षेपकोटिमण्डलापक्रममण्डलयोः भुक्तभागसाम्यमेव स्यात् । तदुक्तं मया ग्रहणनिर्णये—

परमक्षेपकोटिघ्नः पातोनार्कभुजागुणः ।
स्वेष्टविक्षेपकोटयाप्तस्तत्क्षेपकृतियोगतः ॥

पदं यच्चापितं यच्च पातोनार्कभुजाधनुः ।
तद्विशेषं हतं षष्टया गत्यन्तरहृतं क्षिपेत् ॥

पर्वान्ते युक्पदे क्षेपे शोधयेद् विषमे पदे ।
एवंकृतोऽपि पर्वान्तः सूर्येन्द्वोर्ग्रहणे स्फुटम् ॥

(*TSS* 185, p. 102)

These verses are quoted also by Śaṅkara in his commentary on Nīlakaṇṭha's *Tantrasaṅgraha* (on ch. IV, verse 27, *TSS* 188, p. 107) with the introductory remark : तदुक्तमनेनैव ग्रहणनिर्णये ।

9. *Sundararājapraśnottara.* Sundararāja, son of Anantanārāyaṇa, was an astronomer of the Tamil country contemporaneous with Nīlakaṇṭha and author of a detailed commentary on *Vākyakaraṇa* or *Vākyapañcādhyāyī* which is a manual on the basis of which almanacs in the Tamil districts are computed.[1] Sundararāja had the greatest respect for Nīlakaṇṭha whom he addressed for clarification of certain points in astronomy. Nīlakaṇṭha's detailed answers to these questions formed a regular work, *Sundararājapraśnottara.* Manuscripts of this work are yet to come to light, but both authors refer to this work. Sundararāja in his commentary on the last verse of ch. V of the *Vākyakaraṇa* says[2] :

अत्र तु गतियोगांशकेनैव हरणं युक्तमिति श्रीमत्-केरलसद्ग्रामनिवासि-नीलकण्ठार्येण त्रिस्कन्धविद्यापारदृश्वना षड्दर्शनीपारंगतेन आश्वलायनसूत्रेण गर्गगोत्रेण

1. Cr. ed. by T.S. Kuppanna Sastri and K.V. Sarma, K.S.R. Inst., Madras, 1962.

2. *Ibid.*, p. 119.

नवकलरु(?)जातेन गोलचूडामणिना अस्मदनुग्रहार्थे सुन्दरराजप्रश्नोत्तराख्ये ग्रन्थे प्रतिपादितम् । तेन गतियोगेनैव विभज्य स्थितिदलं ज्ञेयम् ।

Nilakaṇṭha too refers to this work in his *ĀBh.Bhāṣya, Gola.*, 48 : *cf.* सुन्दरराजप्रश्नोत्तराख्ये मयोक्तमत्राप्यनुसन्धेयम् । (*TSS* 185, p. 149).

10. A *Grahaṇa-grantha,* copied in continuation of Nīlakaṇṭha's *Siddhāntadarpaṇa-vyākhyā* in the Trivandrum Palace manuscript No. 975. The work as available in this manuscript begins 'अथ ग्रहणम्' and without any more introduction, continues : नन्वेवमपि स्वकाल एव गीतिकोक्त-भगणाद्याः । गीतस्य ग्रहणस्य [च] प्रत्यक्षसंवादः स्यात् । It goes on to describe the necessity of correcting old astronomical constants by observation, deals in detail with the *Śakābda-saṁskāra,* quotes the verses of N's *Parama-guru* Parameśvara from his *Siddhāntadīpikā* (*Mahābhāskarīya-bhāṣya-vyākhyā*),[1] on the latter's observation of some, eclipses, and after some more discussions ends abruptly. There is no doubt that this work is from Nīlakaṇṭha's pen. References herein to his own works, teacher, etc. fully confirm this point. One of his own works is referred to herein thus : अत एव मया छायागणिते तत्साधनतया दृक्क्षेपानयनमुक्तम्—'अन्त्यद्युज्या' etc. (p. 60 of my transcript). The verses quoted are from Nīlakaṇṭha's *Candracchāyagaṇita,* vv. 8-10. He refers to his grand-teacher Parameś-vara and his *ĀBh.Bhāṣya* too, herein : *cf.*, तस्मात् सिद्धान्तदीपिकोदाहृतानि ग्रहणान्यस्माभिर्दृष्टानि च तत्तदवसरे वक्ष्यमाणानि परमेश्वरोक्तप्रकारेण अर्कादिमध्यम-मानीय श्रीपत्युक्तप्रकारेण स्फुटीकृत्य कालक्रिया-गोलपादोक्ताभिरस्माभिर्व्याख्याताभिः युक्तिभिस्सिद्धैः क्रियाविशेषैश्च गण्यन्ताम् ।। (pp. 57-58 of my transcript). The *ĀBh. Bhāṣya* also is referred to elsewhere in this work (*cf.* pp. 62, 63 of the transcript). For a characteristic reference to N's teacher, see : प्रकारान्तरेण 'चन्द्रबाहुफलवर्गे'-त्यादिना श्रीमद्-दामोदराह्वयास्मद्गुरु-मुखोद्गतेन श्लोके-नोक्ता, तद्युक्तिरपि आर्यभटीयान्तर्भूतैव ।। (p. 61 of the transcript).

11. *Grahaparīkṣākrama* (?). The well-known Kerala astrologer Puliyūr Purushottaman Nampūtiri has edited[2] an old, incomplete[3]

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1. Ed. *Madras Govt. Or. Ser.*, 130 (1957).

2. Pub. by the Astrological Research Institute, Bombay-25, 1950.

3. The colophonic words at the end of the edition indicating its completion form only the editor's addition.

Malayalam summary of a Sanskrit work under the title *Grahaparīkṣā-krama*. The textual verses were not available to the editor and he presumed that the author was Dṛgganita-Parameśvara.[1] These verses are, however, found in Nīlakaṇṭha's *Bhāṣya* on the *Golapāda* of the *Ārya-bhaṭīya*, under verse 48 (*TSS* 185, pp. 132-49). It is a long tract of about 200 verses, summing up the principles and methods followed in Hindu astronomy and forms a veritable handbook on the subject. It ends :

इति संक्षेपतः प्रोक्ता परीक्षा ज्योतिषामिह ।
कालमानचतुष्कस्य श्रुतस्य विवृतिस्त्वियम् ॥

It is not however very definite whether this is an independent work with the title *Grahaparīkṣākrama* and is quoted in extenso in the *Bhāṣya* or is but a part of the *Bhāṣya*.

Nīlakaṇṭha should have written more works than those mentioned above since there are quotations attributed to him in later works, for instance, in Śaṅkara's commentary *Laghuvivṛti* on Nīlakaṇṭha's *Tantra-saṅgraha*, which could not be traced to his known works. Again the Trivandrum Palace Ms. No. 975 containing Nīlakaṇṭha's *Siddhānta-darpaṇavyākhyā* and the work on eclipses described above, has, in continuation, some incomplete tracts with no definite titles, which again, to all appearances, seem to be Nīlakaṇṭha's writings.

According to some, Nīlakaṇṭha has composed a work entitled *Grahanirṇaya*.[2] It is likely, however, that this is only the *Grahaṇa-nirṇaya*, noticed above. Ulloor attributes to Nīlakaṇṭha a work called *Gaṇitayukti*. Thus, speaking about a *Bhāṣāyuktibhāṣā*, he says that "it is not the work of Keḷallūr Comātiri, author of *Gaṇitayukti*."[3] The ascription is wrong and the fact is that while our author belonged to the Gārgya-gotra, this latter work is by an anonymous author belonging to

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1. *Vide* the editor's Introduction, p. i ; see also Shri Nampūtiri's review and opinion of *Gaṇitaprakāśikā* by K. V. A. Rama Poduval, Canannore, 1950, p. xiv.

2. Vatakkumkur, *Hist. of Skt. Lit. in Kerala*, vol. I. p. 389 ; Ulloor, *Kerala Sāhitya Caritram*, vol. II, p. 117.

3. Ulloor, *ibid.*, p. 122.

the Bhāradvāja-gotra as is clear from its first verse, which runs as follows :[1]

विदित्वार्यभटप्रोक्तगोलतत्त्वेन केनचित् ।
भारद्वाजेन तन्यन्ते काश्चित् गणितयुक्तयः ॥

Chronology of Nīlakaṇṭha's Works

It has been noticed[2] that Nīlakaṇṭha's *ĀBh. Bhāṣya* is later than his *Tantrasaṅgraha* and *Golasāra* which are quoted in the former. But nothing could be said about the chronology of his other works. The present writer's investigations have, however, shed some light on this matter.

The first five works enumerated above, *viz.*, *Golasāra*, *Siddhāntadarpaṇa*, *Candracchāyāgaṇita*, the commentary thereon, and *Tantrasaṅgraha* do not refer to any other work, but are, in their turn, quoted in other works of Nīlakaṇṭha. Of these, the *Tantrasaṅgraha* is the most comprehensive of the five and gives the date of its composition as 1500 A.D., *i.e.*, it was written when the author was fifty-eight, and on these considerations it may be presumed that the other four works were written before this date. The *Grahaṇanirṇaya* and the *Sundararājapraśnottara*, of which manuscripts have yet to be discovered and which are quoted in the *ĀBh.Bhāṣya*, have also to be ascribed to this period. This *Bhāṣya*, his mature work, Nīlakaṇṭha wrote when he was very old, as he himself remarks : मयाद्य प्रवयसा ··· यथाकथंचिदेव व्याख्यानमारब्धम् (*TSS* 101, p. 156). The *Siddhāntadarpaṇa-vyākhyā* which refers to the *Āryabhaṭīya-Bhāṣya* (*cf.*, com. on verse 25 : एतत् सर्वं मया आर्यभटीयव्याख्याने प्रपञ्चितमिति विरम्यते । p. 22 of my transcript) is still later. And so also his discursive treatise on eclipses which too refers to the *ĀBh.Bhāṣya* more than once ; *cf.*, तत्र कालक्रियापादे सूचितं मया विवृतम् (p. 63 of my transcript) ; एतत् सर्वं गणितपादे विस्तरेणोपपादितः (*ibid.*, 63).

Date of Nīlakaṇṭha

Indisputable evidences are available regarding the date of our author. Śaṅkara, Nīlakaṇṭha's pupil, in his commentary on his teacher's

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1. Ms. : Madras, Mal. D. 339, pp. 83-89, now, transferred to the Kerala Univ. Res. Inst. and Mss. Library, Trivandrum.

2. Ulloor, *Kerala Sāhitya Caritram*, vol. II, p. 119.

Tantrasaṅgraha, points out that the first and last verses of the work contain chronograms specifying the dates of commencement and completion of the work. Thus, after giving the natural meaning of the first verse of the work :

'हे विष्णो निहितं कृत्स्नं' जगत् त्वय्येव कारणे ।
ज्योतिषां ज्योतिषे तस्मै नमो नारायणाय ते ।।

Śaṅkara says : आचार्येण इमं श्लोकं आदितो ब्रुवता प्रथमपादेन प्रबन्धारम्भदिन-कल्यहर्गणश्च अक्षरसंख्यया उपदिष्टः, समाप्तिसमयाहर्गणश्च 'लक्ष्मीशनिहितध्यान' इत्यन्ते भविष्यति ।

These two Kali dates, 16,80,548, and 16,80,553, work out to Kali Year 4601, Mīna 26, and 4602, Meṣa 1, both dates occurring in April 1500.

The *Siddhāntadarpaṇa* and Nīlakaṇṭha's own commentary thereon give the year and actual date of his birth. *Cf.* :

Text : कलिसन्ध्यष्टमांशे स्वशतांशाढ्ये गते ततः ।
धनुर्मिथुनयोर्मध्ये प्रायशस्त्वयने उभे ।।
(*Sid. Dar.* 18)

Com. : दिव्याब्दशतमिता खलु काले सन्ध्या स्मर्यते । तस्य अष्टमांशः सार्धदिव्याब्दद्वादशकः । स च सौराब्दानां पञ्चचत्वारिंशत्-शतमितः (4500)। तस्य शतांशः पञ्चचत्वारिंशदब्दः (45)। ततः स्वशतांशाढ्यः 'शिवशिवे'ति (4545)। कल्यब्दैस्तावति याते उभय अयने उत्तरदक्षिणाख्ये प्रायशो धनुमिथुनमध्ये स्तः । तदा अयनचलनांशाः धनात्मकाः पञ्चदशसंख्या बभूवुः। प्रायिकत्वं च कलाष्टकाधिकत्वात् । यतो भार्गव-परमेश्वरार्येण अस्मत्-परमगुरुणा 'चलांशास्स्वं' (4536) इति कल्यब्दे परीक्ष्य पञ्चदशांशपूर्तिर्निर्णीता । अतः सन्ध्याष्टमांशशतांशस्य प्रायिकत्वम् । स्वजन्मकालज्ञापनार्थं चैवमुक्तम् । तदा अहर्गणश्च 'त्यजाम्यज्ञतां तर्कैः (16,60,181) इति । (Trivandrum Palace Ms. 975 ; p. 14 of my transcript). Here Nīlakaṇṭha himself says that he was born on the Kali day 16,60,181, which works out to A.D. 1443 Dec. (Kali 4545 Vṛścika).

That Nīlakaṇṭha lived to a ripe old age, even to become a centenarian, is attested by a contemporary reference made of him in a Malayalam work on astrology, *viz.*, the *Praśnasāra* by Mādhava, a Nampūtiri brāhman of the Īñcakkāzhvā house in Kerala, who wrote his work in A.D. 1542-43. Here, Mādhava says that he could count upon reputed authorities like 'Keḷanallūr' to recommend his work. *Cf.* :

āḷ-āyat-ādaravil ādiyil Attimattam

lōkōttaran punar-itinn-iha *'Kēḷanallūr'* /

ābhāsar allarivatuḷḷavar ādarippān

porum prasiddhi perikoḷḷavar uṇṭanekam //

The date of composition of this work, *Praśnasāra*, is given as Kali 4644 (A D. 1542-43) by the following verse in the work itself :

ezhunūttorupatteṭṭāvatu Kollam atāya nāḷ /

varunna viṣuvad *bhāvatattvam* (4464) kalyabdam āyatu //

Rightly does Nīlakaṇṭha remark in his *Ā.Bhāṣya* : मयाद्य प्रवयसा ··· ··· यथाकथंचिदेव व्याख्यानमारब्धम् (*TSS* 101, p. 156). Moreover, we know of at least two more works composed by him subsequent to his writing the *ĀBh.Bhāsya*, *viz.*, the commentary on the *Siddhāntadarpaṇa* and the work on eclipses, both of which quote the *ĀBh.Bhāṣya*.

Versatility of Nīlakaṇṭha

For a mere Jyautiṣika and one who had specialised only on its astronomical aspect, Nīlakaṇṭha seems to be very well read. Every other page of his writings substantiate his knowledge of the several branches of Indian philosophy and culture. Sundararāja, the Tamil astronomer, calls him *ṣaḍ-darśanī-pāraṅgata*, 'one who had mastered the six systems of philosophy'.[1] Nīlakaṇṭha himself informs us that he studied Vedānta under Ravi : *cf.*, *Ravita ātta-Vedāntaśāstreṇa*. He can refer to a Mīmāṁsā authority to establish a mathematical point[2] and with equal felicity apply a grammatical dictum to the same purpose.[3] Piṅgala's *Chandas-sūtra*[4] and the lexicons are quoted as the occasion

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1. *Cf.* his commentary on the *Vākyakaraṇa*, 5.19 (edn., p. 119).

2. *Cf. ĀBh.Bhāṣya*, *TSS* 101, pp. 54, 158, where Pārthasārathi Miśra's *Vyāptinirṇaya* and *Advaitavivaraṇa*, and *Ajitā* (com. on *Ślokavārttika*) and its commentary *Vijayā* come in for quotation. On *Golapāda*, 50, the *Bṛhaṭṭīkā* of Kumārila Bhaṭṭa is cited.

3. *Cf.* quotations from the *Vākyapadīya*, *ĀBh.Bhāṣya*, *TSS* 110, p. 31.

4. See *ĀBh.Bhāṣya*, *TSS* 101, p. 4.

demanded. The scriptures and the Dharmaśāstra texts also come in for citation.[1] And, so also the Purāṇas[2] like the *Bhāgavata*[3] and the *Viṣṇu*.[4] As for Jyotiṣa works, Nīlakaṇṭha exhibits a surprising familiarity with a large number of them, from the *Vedāṅga-Jyotiṣa* down to the treatises of his own times. He cites all types of jyotiṣa texts, *Gaṇita*, *Saṁhitā* and *Horā*, but as became his subject of specialisation, his quotations are mainly from texts dealing with astronomy proper. Some of the more important texts of all-India prevalence that Nīlakaṇṭha quotes are : *Vedāṅga-Jyotiṣa*, *Āryabhaṭīya*, Varāhamihira's *Pañcasiddhāntikā*, *Bṛhajjātaka* and *Bṛhatsaṁhitā*, the *Sūryasiddhānta*, Śrīpati's *Siddhāntaśekhara* and Muñjāla's *Laghumānasa*. Of texts common only in Kerala may be mentioned the *Parahitagaṇita* or *Grahacāranibandhana* of Haridatta, *Bhāṣya* by Bhāskara I on the *Āryabhaṭīya*, and Bhāskara's *Laghu* and *Mahā-Bhāskarīyas*, Govindasvāmin's *Bhāṣya* on the latter and Parameśvara's super-commentary thereon ; other works of Parameśvara like his *Āryabhaṭīya-vyākhyā* also come in for citation as also passages from his own teacher Dāmodara. Another Kerala author whom Nīlakaṇṭha quotes profusely is Mādhava, often styled 'Golavid',[5] who was a reputed astronomer of the times. Manuscripts of several works quoted by Nīlakaṇṭha are yet to be unearthed. Indeed, a detailed study of the numerous authorities quoted by Nīlakaṇṭha is bound to throw much light on the history of Hindu astronomy.

Acknowledgements

As indicated earlier, all the manuscripts used for the present

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1. See Com. on *Siddhāntadarpaṇa*, verse 1 ; the Grahaṇa work, pp. 48, 49 ; and *ĀBh.Bhāṣya*, *Golapāda*, verse 48, where the *Taittirīya-upaniṣad*, *Kālanirṇaya* of Sāyaṇa, *Manusmṛti*, etc. are quoted.

2. See Com. on *Siddhāntadarpaṇa*, verse 1.

3. *Cf.*, *ĀBh.Bhāṣya*, *TSS* 110, pp. 16, 26.

4. *Cf.*, *ibid.*, p. 8.

5. On this Mādhava, (*c.* 1340-1425), who was a teacher of Dṛggaṇita-Parameśvara, see the present writer's Introduction to his edition of Mādhava's *Veṇvāroha* (Trippunithura, Cochin, 1957), and *Sphuṭacandrāptiḥ* (Hoshiarpur, 1973).

edition of *Candracchāyāgaṇita* with commentary are preserved in the magnificent manuscripts collection of the Oriental Research Institute and Mss. Library of the Kerala University. I am grateful to the authorities of the Library for making available to me the said manuscripts for use in this edition. A sad interest, however, relates to this publication, in that Shri N. Rama Sastri, Senior Pandit in the Library, who copied the main manuscript for me, is no more. To Prof. T.S. Kuppanna Sastry, lately of the Presidency College, Madras, I am highly obliged for the help rendered towards the translation of the work. The V. V. R. I. Press deserves to be complimented for the efficient and prompt printing of the work in spite of its heavy and pressing work schedule.

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Hoshiarpur,
'*Śaṅkara Jayanti*',
May 4, 1976

नीलकण्ठ-सोमयाजि-विरचितं

चन्द्रच्छायागणितम्

COMPUTATIONS CONCERNING MOON'S SHADOW

By

NĪLAKAṆṬHA SOMAYĀJI

नीलकण्ठ-सोमयाजि-विरचितं

चन्द्रच्छायागणितम्

१. कालात् छायागणितम्*

[वस्तुनिर्देशः]

[1]सूर्येन्दू तुङ्ग[2]पातौ च तदानीमयनांशकान् ।
तद्देशाक्षं च निर्णीय गण्यतां शशिनः प्रभा ॥ १ ॥

[1]जन्मस्थितिहृतयः स्युर्जगतो यस्मात् प्रणम्य तद् ब्रह्म ।
चन्द्रच्छायागणितं कर्त्रा व्याख्यायतेऽस्य गार्ग्येण ॥

तत्र सूर्येन्दुस्मरणेन मङ्गलाचरणमपि कृतम् । अस्यायमभिप्रायः— सूर्येन्दुतुङ्गपातमध्यमध्रुवान् अहर्गणविशिष्टायनचलनं तद्गुणकारहारपरिधींश्च स्वदेशाक्षदेशान्तरं च गोलवित् परीक्षकगुरूपदेशतोऽवगम्य मध्यममानीय स्फुटीकृत्य चन्द्रच्छाया वक्ष्यमाणप्रकारेण गण्यताम् इति । छायागणनस्य गोलयुक्तिसिद्धत्वात् तदेवेह सुसूक्ष्मो वक्ष्यते । गुणहरयोः स्थौल्यान्मध्यमानां कालान्तरेषु स्थूलतासम्भवात् तत्कालभवैः परीक्षकैरेव ध्रुवा निबद्धव्याः ॥ १ ॥

[शशिनः स्फुटविक्षेपः]

खागाश्विघ्नान्त्यकर्णाप्ता दोर्ज्या क्षेपो विधोर्व्यहेः ।
सौम्यो याम्योऽथ [3]कोटिस्तत्त्रिज्यावर्गान्तरात् पदम् ॥ २ ॥

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* 'छायागणितम्' इत्यस्य 'कालात् छायायाः गणितम्', 'छायायाः कालस्य गणितम्' इत्युभयथा विग्रहः ।

मूलम्— 1. Mss. used : A. No. 5862-B ; B. No. 5867 (ff. 173-77) ; C. No. 475 (f. 65), all from the Kerala Univ. Or. Mss. Inst. and Mss. Lib., Trivandrum.

2. B. सूर्येन्दुतुङ्गे ; C. तुङ्ग frayed out.

3. A. adds here तत्

व्याख्या—1. Ms. used : A. No. 5862-B. being the same as text no. A.

COMPUTATIONS CONCERNING MOON'S SHADOW

By

NĪLAKAṆṬHA SOMAYĀJĪ

I. COMPUTATION OF SHADOW FROM TIME

(Introduction)

1. Let the Moon's Shadow (*prabhā*)[1] be computed after determining the true sun and moon, the moon's apogee and ascending node, the *ayanāṁśa*[2] at the time and the latitude of the place (for which the computation is made).

(The Moon's True Latitude)

2. The R[3] sine of the 'true moon-*minus*-ascending node' multiplied by 270 and divided by the 'Last Hypotenuse', is the true latitude of the moon. It is north or south, (respectively, for the first two quadrants and the last two quadrants). The square root of [its square subtracted from R^2], is the 'perpendicular' (*koṭi*).

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1. *Prabhā* is used in the sense of 'shadow' on account of the equivalence between their measure.

2. *Ayanāṁśa* is the distance of the Vernal equinox-point from the first point of the Indian Zodiac, *i. e.*, the First point of the sign Meṣa.

3. R = त्रिज्या of 3438 units.

खागाश्वि (२७०) घ्नेत्यनेन विक्षेपतत्कोटचोरानयनमुच्यते । प्रसिद्धं चन्द्रस्फुटं विन्यस्य पातं विशोध्य याम्योत्तरगोलमवगम्य भुजाया 'मख्या'(२२५)दि-जीवां गृहीत्वा तां **खागाश्विभिः** 'असुर'संख्यैः (२७०) निहत्य वक्ष्यमाणे-नान्त्यकर्णेन द्वितीयस्फुटकर्णेन हरेत् । तत्र यल्लब्धं स चन्द्रस्य विक्षेपः । स च पातोनचन्द्रे मेषादौ **सौम्यः**, तुलादौ **याम्यः** । एवमेवात्र छायागणने विक्षेप आनेयः । व्यतीपाते तु त्रिज्ययैव हृत्वाऽऽनेयः । न द्वितीयस्फुटकर्णेन । अथ तद्विक्षेपं वर्गीकृत्य **त्रिज्यवर्गाद्** विशोध्य मूलीकुर्यात् । सा विक्षेपकोटिः । ते विक्षेपतत्कोटी रक्षणीये ॥ २ ॥

[चन्द्रस्य द्वितीयस्फुटः]

इतोऽन्यद् यत्कर्म तद् द्वितीयस्फुटचन्द्रादेव इति प्रथमं द्वितीयं स्फुटी-करणमुच्यते **इन्दूच्चोनार्ककोटिघ्नेत्यादिभिस्त्रिभिः**—

इन्दूच्चोनार्ककोटिघ्नतिथिदोःकोटिविंशयोः ।
त्रिज्यांशौ स्फुटभुक्तिघ्नौ मध्ययाप्तौ विधोः फले ॥ ३ ॥

त्रिज्यायां कोटिजं स्वर्णमयनैक्यभिदावशात् ।
तद्बाहुफलवर्गैक्यमूलमन्त्यश्रुतिर्विधोः ॥ ४ ॥

त्रिज्याघ्नं दोःफलं स्वर्णं कर्णाप्तं स्याद् विधोः स्फुटे ।
कर्क्येणादौ वितुङ्गेऽर्के शुक्लपक्षेऽन्यथाऽसिते ॥ ५ ॥

अर्कस्फुटं विन्यस्य इन्दूच्चं विशोध्य कोटचा जीवां गृहीत्वा तां क्वचि-द्विन्यस्य पुनश्चन्द्रस्फुटादर्कस्फुटं विशोधयेत् । तत्र शिष्टं **तिथिशब्देन** विवक्षितम् । तस्य भुजाकोटचोर्जीवे गृहीत्वा उभे **इन्दूच्चोनार्ककोटचा** निहत्य द्वे अपि **विंशत्या** हृत्वाऽऽप्तं फलद्वयमपि पृथक् **त्रिज्यया** हृत्वा तत्फले द्वे अपि चन्द्रस्फुटगत्या हत्वा **मध्यभुक्त्या** हृत्वाऽऽप्ते दोःकोटि**फले** स्याताम् । तत्र यत् कोटिफलं तत् **त्रिज्यायाम्** इन्दूच्चोनार्कस्य च अर्कोनचन्द्रस्य च अयनैक्ये धनं कुर्यात् । अयनभेदे ऋणं च कुर्यात् । तस्य च भुजाफलस्य च वर्गयोगमूलम् इह अन्त्यकर्ण उक्तः । पुनरपि भुजाफलं विन्यस्य त्रिज्यया हत्वाऽनेनान्त्यकर्णेन हृत्वाऽऽप्तं भुजाफलं चन्द्रस्फुटे धनमृणं वा कुर्यात् । तत्र पूर्वपक्षे इन्दूच्चोनार्के कर्क्यादिगे चन्द्रस्फुटे धनम्, मकरादावृणम् । अपरपक्षे वितुङ्गेऽर्के कर्क्यादावृणम्, मकरादौ धनमिति विभागः । एवं चन्द्रस्य द्वितीयस्फुटकर्म ।

चन्द्रस्य प्रथमस्फुटभुक्तिः— **तुङ्गोनेन्दुमध्यमदोर्ज्यान्तरं** 'सूनु'(७)घ्नं 'गात्रैः' (२३) हृतं कर्क्यादौ केन्द्रे स्वमध्यमगतौ धनम्, मृगादावृणम् । तदा प्रथमस्फुटगतिः स्यात् ॥ ३-५ ॥

(The Second-Inequatity-Correction)[4]

3. The R cosine of the 'true sun-*minus*-moon's apogee' × R sine, or R cosine, respectively, of the equation of the 'centre-corrected-moon-*minus*-true sun' × the equation of the 'centre-corrected-moon's daily motion' ÷ (20 × R × the moon's daily mean motion) is, respectively, the moon's *bhujā-phala* and *koṭi-phala*.

4. Add to or subtract from R, the *koṭi-phala* according as the 'true sun-*minus*-moon's apogee' and the 'equation of the centre-corrected-moon-*minus*-true sun' are both in the same *ayana* (*i.e.*, from 90° to 270° or from 270° to 90°), or in different *ayanas* (*i.e.*, one is from 90 to 270° and the other is from 270° to 90°). Square this and add to the square of the *bhujā-phala*. Find the square root. This is the 'Last Hypotenuse'.

5. R × *bhujā-phala* ÷ the 'Last Hypotenuse' is to be added or subtracted from the equation of the 'centre-corrected-moon', as the 'true sun-*minus*-apogee' is from Cancer or Capricorn, (*i.e.*, between 90° and 270°, or between 270° and 90°) if it is the light fortnight (*i.e.*, if 'moon-*minus*-sun' is between 0° and 180°). Reverse the addition and subtraction if it is the dark fortnight (*i.e.*, if 'moon-*minus*-sun' is between 180° and 360°).

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4. This is called Evection. First, Vaṭeśvara (904 A.D.), then Muñjāla (932 A. D.), and after him Śrīpati (999 A. D.) gave this correction in Hindu astronomy.

[गतिसंस्कारः]

व्यासार्धघ्ना स्फुटा भुक्तिरन्त्यकर्णोद्धृताऽत्र तु ।
चन्द्रोऽयमयनांशैश्च संस्कृतो भास्करोऽपि च ॥ ६ ॥

अथार्धेन गतिसंस्कारमाह [व्यासार्धघ्ना] इति । चन्द्रस्फुटभुक्तिं व्यासार्धेन हत्वा अन्त्यकर्णेन हृत्वाऽऽप्तमत्र छायाकर्मणि चन्द्रगतिर्ग्राह्या ॥ ६a ॥

उत्तरार्धेन रवीन्द्वोश्च विशेषमाह—[चन्द्रोऽयम्] इति । चन्द्रोऽयं द्वितीयस्फुटसिद्धः अयनचलनेन च संस्कृतोऽत्र ग्राह्यः । भास्करोऽप्ययनचलनेन संस्कृत एव । नक्षत्राद्यवगतौ प्रथमस्फुटसिद्ध एव चन्द्रो ग्राह्यः । तत्र न द्वितीयस्फुटभुजाफलमयनचलनं च संस्कार्यम् । व्यतीपाते त्वयनचलनं संस्कार्यम्, न द्वितीयस्फुटभुजाफलम्, द्वितीयस्फुटस्य लम्बनवद् दृग्विषयत्वात् । ग्रहणग्रहयोगादौ दृग्विषये सर्वत्र द्वितीयस्फुटसिद्ध एव चन्द्रो ग्राह्यः ॥ ६b ॥

[काललग्नं प्राग्लग्नं च]

युग्मौजपदयोः स्वर्णं रवौ स्वा[4]सुकलान्तम् ।
तुलाजाद्योश्चरप्राणा, गतैष्याश्च दिवानिशोः[5] ॥ ७ ॥

स हि कालः, पृथक्स्थेऽत्र चरं चासुकलान्तरम् ।
व्यस्तं कार्यं ततश्चाप्तं [6]मुहुर्लग्नं च तद् दृढम्[7] ॥ ८ ॥

अथ श्लोकद्वयेन छायासाधनस्य लग्नस्यानयनमाह— [युग्मौजपदयोः] इति । अत्रोक्तं तात्कालिकार्कं पृथग् विन्यस्य भुजायाः प्राणकलान्तरं च गृह्णीयात् । तत्र प्राणकलान्तरं 'धियोनु' (२९) आदिकं सार्वत्रिकमेव । चरप्राणाः प्रतिदेशं नानाभूताः । ततोऽभीष्टदेशजा ग्राह्याः । द्वयमपि कलात्मकम् । तत्र प्राणकलान्तरं युग्मौजपदयोः क्रमेण रविकलासु स्वर्णम् । चरप्राणा मेषादावृणं तुलादौ धनम् । एतदुभयमपि संस्कृत्य तस्मिन्नेवार्के दिवा गतप्राणाश्च योज्याः । ते षष्टयाद्यारोपिता रवेर्भगान् राशींश्च प्रविशन्ति । निशि चेद् इष्टकालात्प्रभृत्यु-

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मूलम्— 4. C. रवौ स्वा frayed out. 5. C. दिवानिशोः frayed out.
6. C. मुहुर्ल frayed.
7. C. ढम् to याम्यो (verse 10d), which occur in the bottom line of the obverse of the folio and top line of the reverse, are frayed out, leaving but traces of the letters, which however, do not indicate any variant reading.

(Correction to daily motion)

6. The daily motion of the equation of the centre-corrected-moon × R ÷ the Last Hypotenuse is the daily motion to the used here, *i.e.*, in the computation of the moon's shadow.[5] Add the *ayanāṁśa* to this corrected moon, and to the true sun (and use them).

(Kālalagna and the Orient ecliptic point)

7. Add to or subtract from the true sun of the time taken, the Reduction to the equator (Red. eq.) at one minute of arc per *prāṇa* as the sun is in the even or odd quadrants. Add or subtract the ascensional difference (*cara*) of the (latitude of the) place in *prāṇas* (taken as minutes of arc) as the sun is (in the six signs) from Libra, (*Tulā*), or Aries (*Meṣa*), respectively. Also add or subtract the *prāṇas* (taken as minutes of arc), of the time gone after sunrise, or to go before sunrise, respectively.

8. This is called *Kāla(lagna)*. Place this separately (in two places) and find the ascensional difference and the reduction to the equator pertaining to this (in minutes of arc). Add or subtract them in the reverse order (to that mentioned in verse 7), to the *Kalalagna*. Repeat this operation several times. The exact Orient ecliptic point (Oep) (*Lagna* or *Prāg-lagna*) is obtained.

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5. Though this rate of motion is given as per day, it pertains to the moment taken for computing the shadow.

दयावधिकाः प्राणाश्चरप्राणकलान्तरसंस्कृतरवेर्विशोध्याः । एवं त्रिभिः संस्कृतः स रविः **कालात्मकं लग्नं**, घटिकामण्डलगतं लग्नमिति यावत्। ततोऽपक्रमलग्न-मानेयम् । कथम् ? तदर्थमेतत् काललग्नं पृथग्विन्यस्य प्राग्वद् भुजायाश्चरं प्राणकलान्तरं च गृहीत्वा तस्मिन्नेव काललग्ने **व्यस्तं** कुर्यात्। प्राणकलान्तरम् ओजे धनम् ऋणं युग्मे, चरदलम् मेषादौ धनं तुलादावृणं च कुर्यात्। एवमानीतं क्षेत्रलग्नं स्थूलम्। अतोऽस्याऽविशेषः कार्यः। तदुक्तम्—**ततश्चाप्तं मुहुर्लग्नं च तद् दृढमिति** । तदुभयसंस्कृतात् काललग्नाच्चरं प्राणकलान्तरं च गृहीत्वा केवल एव काललग्ने प्राणकलान्तरम् ओजे धनं युग्मे ऋणं च चरमपि गोलयोर्धनमृणं च कुर्याद् इति चकारेण द्योत्यते। एवं मुहुः पुनः पुनः कुर्याद् यावदविशेषः। दृढमविशिष्टं तत् प्रसिद्धं लग्नं च स्यात् ॥ ७-८ ॥

[दृक्क्षेपः]

अन्त्यद्युज्याहताक्षाद् यत् त्रिज्याप्तं यश्च लम्बकः ।
काललग्नोत्थकोटिघ्नः करार्थाब्ध्युरगैर्हृतः ॥ ९ ॥

दृक्क्षेपस्तद्भिदैक्यं च काले कर्किमृगादिगे[8] ।
विश्लेषे[9] लम्बजाधिक्ये सौम्यो, याम्योऽन्यदा सदा[10] ॥ १० ॥

अथ श्लोकद्वयेन दृक्क्षेपानयनमुच्यते— [**अन्त्यद्युज्याहताक्षाद्**] इति । अन्त्यस्वाहोरात्रज्या परमापक्रमकोटिः। सा 'कविकुलम्' (३१४१) इति। तया **अन्त्यद्युज्यया** स्वदेशाक्षज्यां हत्वा **त्रिज्यया** हृत्वाऽऽप्तं **यत् तत्** स्वदेशजमवधार्यम्। ततो लग्नार्थमानीतस्य **काललग्नस्य कोटिज्यां** गृहीत्वा तया स्वदेशलम्बज्यां हत्वा **करार्थाब्ध्युरगैः** 'प्रणवादि' (८४५२) संख्यैराप्तं च यत् काललग्ने **मृगादिगे** तद्द्वयं संयोज्यम्। **कर्क्यादिगे** तु वियोज्यम्। स **दृक्क्षेपः**। स च दक्षिणः। यदा पुनरक्षात् सिद्धं लम्बकानीताद् विशोध्यते तदैव **सौम्यः** वियोगेऽप्यक्षाल्लब्धस्याऽ**धिक्ये याम्य** एव, अक्षस्य नित्यदक्षिणत्वात् ॥ ९-१० ॥

मूलम्— 8. **A. B.** give an alt. reading के for गे
9. **B. C.** विश्लेष for विश्लेषे
10. **B. C.** यदा ; **B.** gives also सदा as alt. reading.

(The Zenith distance of the Nonagesimal, Zdn)

9. (a) Multiply the R sine of the latitude of the place by the final semi-day-diameter (*i.e.*, R cos 24°) and divide by R. (b) Multiply the R cosine of latitude of the place by the R cosine of the *Kālalagna*, and divide by 8452.

10. The difference of the two, or sum, is the Zenith distance of the nonagesimal (Zdn), when the *Kālalagna* is, respectively, in the six signs beginning from Cancer or in the six signs beginning from Capricorn. In the case of the difference, if the part using R cosine of place (*i.e.*, b) is greater, the Zdn is north. Otherwise, and in the case of the sum, it is south, always.

[चन्द्रच्छाया]

क्षेपदृक्क्षेपचापैक्यं[11] नतिः साम्येऽन्यथान्तरम् ।
राशित्रयं तदूनं यत् तज्ज्याशङ्कुः पराभिधः ॥ ११ ॥

चन्द्रोनलग्नबाहूना त्रिज्या जूकादिजान्विता ।
क्षेपकोटया हता, भक्ता त्रिज्यया बाण उच्यते ॥ १२ ॥

ततो दृक्क्षेपकोटिघ्नात् त्रिज्याप्तं[12] परतस्त्यजेत् ।
शेषः शङ्कुः शशाङ्कस्य तत्कोटिर्महती प्रभा ॥ १३ ॥

अथैकेन परशङ्क्वानयनमाह—[क्षेपदृक्क्षेपचापैक्यम्] इति । पूर्वानीतं विक्षेपं दृक्क्षेपं च चापीकृत्य दिक्साम्ये योजयेत्, दिग्भेदे वियोजयेत् । सा नतिः । विश्लेषे शिष्टस्य दिग् ग्राह्या । तदूनं नत्यूनं राशित्रयं 'नानावर्ण'-(५४००)संख्यं कलात्मकं यत् ततो जीवां गृह्णीयात् । सा परशङ्कुः ॥ ११ ॥

अथैकेन बाणानयनमाह— [चन्द्रोनलग्नबाहूना] इति । उदयलग्नाच्चन्द्रं विशोध्य बाहुज्यामानीय व्यासार्धाच्छोधयेत् । तत्र शिष्टं [क्षेपकोटया हतं त्रिज्यया भक्तं] बाणः । उदयास्तमयासन्नकाले कदाचिच्चन्द्रोनलग्नस्य जूकादित्वमपि सम्भवति । तदा जूकादिजया बाहुज्ययाऽन्विता संयुता सा क्षेपकोटया हता त्रिज्यया भक्ताऽत्र बाण उच्यते ॥ १२ ॥

अथैकेन महाशङ्कुच्छाये अभिधीयेते—[शेषः शङ्कुः] इति । ततो बाणाद् दृक्क्षेपकोटया हतात् त्रिज्यया हृत्वाऽऽप्तं पूर्वानीतात् पराभिधाच्छङ्कोस्त्यजेत् । तत्र शेषः शशाङ्कस्य तात्कालिकः शङ्कुः । तत्कोटिश्च महाच्छाया । सर्वत्र कोटिशब्देन स्वत्रिज्यावर्गान्तरपदमुच्यते ॥ १३ ॥

मूलम्—11. C. क्यं to क्षेपकोटया (verse 12), frayed away, leaving only traces.

12. C. ज्या in त्रिज्याप्तं omitted.

(The Moon's Shadow)

11. The sum or difference of the Zdn and the moon's latitude, when they are of the same or different directions, respectively, is called *Nati.* The R sine of the angle got by subtracting the *Nati* from three signs, is called *Para-Śaṅku.*

12. R *minus* or *plus* R sine (Oep-*minus*-moon), respectively, when (Oep-*minus*-moon) is in the six signs from Aries or Libra, multiplied by R cos moon's latitude and divided by R, is called *Bāṇa.*

13. *Bāṇa* multiplied by R cos Zdn and divided by R is to be subtracted from the *Para-Śaṅku*. This is the Great Gnomon (*Mahatī prabhā* or *Mahā-Śaṅku*) of the moon, (*i.e., Maha-Śaṅku*= R sine altitude the moon). Its R cosine is the Great Shadow (*Mahā-Chāyā*).

सेष्ट[13]शङ्कुहता भुक्तितिथ्यंशोनेन शङ्कु[14]ना ।
महताऽऽप्ता ततः स्पष्टा भवतीह शशिप्रभा ॥ १४ ॥

अथैकेनाभ्यां शङ्कुच्छायाभ्यां द्वादशाङ्गुलशङ्कुच्छायानयनमाह—सेष्टशङ्कुहता इति । सा महाच्छाया इष्टशङ्कुहता द्वादशहता द्वितीयस्फुटभुक्तिपञ्चदशांशोनेन महाशङ्कुना हृता चन्द्रस्य छाया स्फुटा भवति । द्वादशाङ्गुलशङ्कोश्छाया अङ्गुलात्मिका भवतीत्यर्थः । यदा पदानि ज्ञेयानि तदा महाच्छायां सार्धैः षड्भिर्हत्वा भुक्ति'तिथ्यं'शोनेन (१५) महाशङ्कुना हरेत् । तत्र लब्धानि छायपदानि । तत्र शेषम् अष्टघ्नं तेनैव हारेण हरेत् । तत्राङ्गुलानि स्युः । एवमादिसिद्धयर्थमिहेष्टशङ्कुहननमुक्तम् । अत्र पाठ्यम्—

अर्का(१२)ङ्गुलशङ्कोर्भा विश्वा(२३)हता 'जिन'(२४)हृताथ पदभा स्यात् ।
शिष्टात् त्रिभिरेवाप्तान्यत्र भवन्त्यङ्गुलानि पुनः ॥

तत्र च शिष्टं विंशतिगुणितमथ व्यङ्गुलानि स्युः ।
अङ्गुलषष्ट्यंशो हि व्यङ्गुलमत्राङ्गुलं पदाष्टांशः ॥

तुलाजादिक्रान्त्युत्थचरगतगम्यासुयुतितद्-
भिदोनद्वयक्षोत्थं गुणमपमकोट्यैव गुणितम् ।
त्रिराशिज्याभक्तं त्वथ सदलषट्केन गुणितं
महाशङ्क्वाप्तं तन्निजपदमितां विद्धि समभाम् ॥

[चन्द्रच्छायानयने प्रकारान्तरम्]

बाणदृक्क्षेपघाताद् यत् त्रिज्याप्तं तन्नतिज्ययोः ।
अन्तरं बाहुरन्यत्वे नतेर्दृक्क्षेपतो युतिः ॥ १५ ॥
लग्नोनशशिकोटिघ्ना [15]क्षेपकोटिस्त्रिजीवया ।
हार्या, तद्बाहुवर्गैक्यमूलं च महती प्रभा ॥ १६ ॥
तत्कोटिश्च महाशङ्कुः प्राग्वदिष्टप्रभा ततः ।
शङ्कोः शोध्यान्महत्वेऽर्काद् दृश्यो नाडीद्वयान्तरे ॥ १७ ॥

मूलम्—13. B. C. स्वेष्ट for सेष्ट 14. C. शोनेन शङ्कु frayed out.
15. C. क्षे frayed out.

14. The Great Shadow, multiplied by a gnomon of any length, and divided by the 'Great Gnomon -*minus*-the fifteenth part of the rate of motion of the moon per day[6] is the Correct Shadow of the moon (measured in the same unit as the gnomon used).

(Alternative method for the Moon's Shadow)

15. Find the product of the *Bāṇa* got above (in verse 12) and the R sine of Zdn, divided by R. The difference between this and the R sine of *Nati* (got in verse 11) is called *Bāhu* (*i.e.*, base), if the *Nati* is of the same direction as the Zdn. If of different directions their sum (instead of their difference) is the *Bāhu*.

16. R cos latitude of the moon should be multiplied by R cos 'moon-*minus*-Oep' and divided by R. The square root got by adding the square of this and the square of *Bāhu* is the Great Shadow.

17. The perpendicular, (*i. e.*, R cosine), of this, (*i. e.*, $\sqrt{(R^2 - \text{Great Shadow}^2)}$, is the Great Gnomon. From this, the moon's shadow of the desired time is to be got, (as before).[7]

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6. The purpose of subtracting the 15th part of the daily rate of motion is to correct the Great Gnomon for parallax of the moon, which depresses the moon by about 53′ in the mean near the horizon and proportionately elsewhere along the vertical circle, and lessens its apparent altitude upon which the shadow depends. Hindu astronomers take the horizontal parallax proportionate to the true daily rate of motion, though this is a bit rough.

7. The second half is not clear : "शङ्कोः शोध्यान्महत्वे दृश्यः", "The moon will be visible provided the Great Gnomon is greater than the quantity to be subtracted, (*i.e.*, the 15th part of the daily motion, in verse 14)." Otherwise the moon will be below the horizon. This half is not commented upon by the author.

एवमेकेन प्रकारेण छायानयनमुक्त्वा प्रकारान्तरेणाप्याह सार्धेन श्लोकद्वयेन। अत्रापि वाणानयनान्तं कर्म प्राग्वदेव कुर्यात्। तत्र यौ **बाणदृक्क्षेपौ तयोर्घाताद्भ्यासाद्** व्यासार्धेन हृतं **यत्** तस्य पूर्वोक्तनतिचापज्यायाश्च **यदन्तरं स** इह वाहुः। नतिदृक्क्षेपयोर्दिक्साम्ये वाणदक्क्षेपघातात् त्रिज्याप्तस्य नतिज्यायाश्चान्तरं वाहुः। दृक्क्षेपान्नतेरन्यदिक्त्वे तु फलनतिज्ययोर्योग एव वाहुः। नतेरन्यदिक्त्वं च दृक्क्षेपाद् विपरीतदिक्कस्य विक्षेपस्याधिक्य एव भवति। तत्कोटिसिद्धये **लग्नोनशशिकोटिज्यया** तत्कालविक्षेपकोटिं हत्वा त्रिज्यया हरेत्। तत्र लब्धायाः कोटचा **बाहोश्च वर्गयोगमूलं** महाच्छाया स्यात्। त्रिज्यात्मककर्णस्य छायात्मकवाहोश्च या कोटिः स चेह शङ्कुः स्यात्॥ १५-१७॥

२. छायायाः कालानयनम्

[विपरीतच्छायानयने साधनानि]

यदीन्दोर्भादिभिः प्रश्नः ससूर्यो लग्नतः [16]शशी।
अहिस्तुङ्गो दृगैक्यार्थं गण्याः प्रभयामुया॥ १८॥

एवमपक्रमादिभिर्विना छायानयनमुभयथा प्रदर्श्य पुनरपक्रमादिभिर्विपरीतच्छायानयनं प्रदर्शयितुं तत्साधनभूततत्कालचन्द्राद्यानयने इतरेतराश्रयदोषं परिहर्तुं अविशेषकार्येऽपि प्रथममूहसिद्धलग्नद्वारा तत्कालचन्द्राद्यानयने लाघवं स्यादिति तदर्थमाह—[**यदीन्दो**] इति।

यदि चन्द्रस्य छायादिकमुद्दिश्य कालविषयः **प्रश्नः** क्रियते तदाऽमुया पृच्छकेनोद्दिष्टच्छायया प्रथमं लग्नमभ्यूह्य नाडिकाकरणं कृत्वा तत्कालार्कचन्द्रतत्तुङ्गपातान् गणयित्वा अपक्रमानयनादिकं वक्ष्यमाणं कर्म कुर्यादित्यर्थः। **भादिभिरित्यत्र** आदिशब्देन दिनविशेषः कालविशेषश्च विवक्ष्यते। वाक्यध्रुवयोगादिना तत्कालस्फुटचन्द्रे सिद्धे सति किमर्थं पुनस्तुङ्गानयनमित्यत आह— **दृगैक्यार्थमिति**। दृक्साम्याय द्वितीयस्फुटकर्म कर्तुमित्यभिप्रायः।

एतदुक्तं भवति—प्रथमं छायावाक्यैः स्वदेशपठितैश्चन्द्रस्य गतनाडीर्गन्तव्यनाडीर्वा अवगम्य ऊहसिद्धतत्कालचन्द्रेण छायावाक्यसिद्धनाडिकाभिश्च लग्नमानीय तल्लग्नार्कान्तरनाडिकाश्चानयेत्। कथं पुनर्नाडिकाकरणम्? उच्यते। सायनं लग्नं पृथग्विन्यस्य चरं प्राणकलान्तरं च गृहीत्वा चरदलं षष्टचा समारोप्य सायनलग्ने मेषादिके ऋणं कुर्यात्। तुलादिके योजयेत्। प्राणकलान्तरमपि कलादिकमोजपदजं लग्नात् त्यजेत्। युग्मपदजं प्रक्षिपेत्। एवं तत्कालसायनार्के च तद्द्वयं कुर्यात्। तदा लग्नकालः सूर्यकालश्च स्याताम्।

16. C. श frayed out.

II. COMPUTING THE TIME FROM THE SHADOW

(Bases for Viparītacchāyā)

18. If the problem is to find the *exact time*, given the moon's shadow together with other requirements (like the date and rough time of day)[8] then, by using the shadow and the rough time and *lagna*, the sun and the moon, and the moon's node, and its apogee for the sake of computing the second inequality corrected moon, are to be computed.

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8. Time from shadow is multivalued. Thus, for a given shadow, even on the same day, we can have two times, one with the moon being east of the meridian, and the other west, not to speak of different days. That is why the rough time when such length of shadow will occur, is required, which is obtained from tables constructed for different places, connecting the shadow with the time.

तयोर्लग्नकालात् सूर्यकालं विशोध्य शिष्टान् राशीन् पञ्चभिर्हत्वा भागादिकं दशभिश्च हत्वा लिप्ताभ्यः षष्टयाप्तं भागेषु समारोप्य भागेभ्यश्च षष्टयैव हृतं पञ्चगुणितेषु राशिषु क्षिपेत्। तत्र राशिस्थानगता नाड्यः। भागस्थानगताश्च विनाड्यः। कलास्थानगतानि गुर्वक्षराणि। एवमुदयात् प्रभृति याता नाडिकाः स्युः। ताश्च दिनमानादधिकाः स्युस्तदा ततो दिनमानं विशोध्य शिष्टं रात्रिगतनाड्यादिकमिति ज्ञेयम्। यदि पुनः सूर्यकालाल्लग्नकालं विशोध्य नाडिका क्रियते तदा रात्रिशेषनाडिकाः स्युरिति विशेषः ॥ १८ ॥

[चतुर्यासाधनम्]

[17]परमापक्रमकोट्या विक्षेपज्यां निहत्य, तत्कोट्या।
इष्टक्रान्तिं चोभे त्रिज्याप्ते योगविरहयोग्ये स्तः ॥ १९ ॥

सदिशोः संयुतिरनयोर्वियुति[18]र्विदिशोरपक्रमः स्पष्टः।
स्पष्टापक्रमकोटिर्द्युज्याविक्षेपमण्डले वसताम् ॥ २० ॥

क्रान्तिज्या विषुवद्भाघ्ना क्षितिज्या द्वादशोद्धृता।
व्यासार्धघ्ना द्युजीवाप्ता चापिता स्युश्चरासवः ॥ २१ ॥

अथ विक्षेपवतां चतुःसाधने विशेषः प्रदर्श्यते। 'भा'(24)पक्रम इत्युक्तः परमापक्रमः। स च चापात्मकः, अंशकशब्देनोक्तत्वात्। तत्कोटिचापं च षट्षष्ट्यंशात्मकम्। तयोर्जीवे चानीय पठिते—

> 'सौरिः शक्यं' (2715) 'वधो लोके' (1398) संस्कारो लग्नवत् किल।
> अपमज्याद्युविष्कम्भदलज्ये क्रमशोऽन्तिमे ॥

इति। तत्र परमापक्रमकोट्या चन्द्रस्य तत्कालविक्षेपज्यां निहत्य इष्टविक्षेपकोट्या इष्टापक्रमज्यां च हत्वा उभे त्रिज्यया हृते योगविरहयोग्ये भवतः। कदा योगः कार्यः, कदा वा वियोग इत्याह—सदिशोः संयुतिरनयोर्वियुतिर्विदिशोरिति। समानदिशयोरनयोः संयुतिः कार्या। भिन्नदिशोर्वियुतिश्च। किं पुनरत्र साध्यते ?

17. Verses 19 and 20 are quotations from Mādhava of Saṅgamagrāma and have been quoted by Nīlakaṇṭha himself in his *Āryabhaṭīya-Bhāṣya*, *Golapāda* (*TSS* 185, p. 108) with the introductory statement : अत एव गोलविदा माधवेन विक्षेपवतां स्फुटापक्रमानयने गणितविशेषः प्रदर्शितः। See also the *Karaṇapaddhati* of Putumana Somayāji, 9. 9-10.

18. B. वियुति left out.

(The four main R sines)

19. Multiply the R sine of moon's latitude by the R cosine of the greatest declination (*viz.*, 24° according to Hindu astronomy). Multiply the R sine of the declination by the R cosine of the moon's latitude. Divide each product by R. These two products are to be added or subtracted one from the other (according to the instruction in verse 20)

20. Add the two products, if the declination and the latitude are of the same direction ; if not, subtract one from the other. The result is the R sine of the true declination of the body in its own orbit. Its R cosine is the radius of the diurnal circle of the body.

21. The R sine of the true declination, multiplied by the equinoctial shadow and divided by 12, is called the Earth-sine (*Kṣitijya*). This multiplied by R, and divided by the radius of the diurnal circle is the sine of the *Cara*, its arc being the *Cara* in *prāṇas* (*Carāsu* or *Caraprāṇa*).

विक्षेपवतां स्फुटापक्रमः । तस्य स्फुटापक्रमस्य कोटिः तेषामपि द्युज्या स्यात् । येयं स्फुटापक्रमज्या सा विषुवच्छाघ्ना द्वादशोद्धृता क्षितिज्या भवति । सा च व्यासार्धेन हता स्वया द्युजीवया हृता चापिता च चरासवः स्युः । एते क्षितिज्याचरज्यानयने रवेरपि साधारणे ॥ १९-२१ ॥

[दृक्कर्म]

विक्षेपदृक्क्षेपवधे त्रिमौर्व्या निहत्य तत्कोटिवधेन भक्ते ।
धनुर्धनर्णं हरिदैक्यभेदात् तयोः शशाङ्काद्युदयेऽन्यथाऽस्ते ॥ २२ ॥

एवं साधनचतुष्कमानीय दर्शनसंस्कारः कार्य इति तदनन्तरं दर्शनसंस्कारः प्रदर्श्यते [विक्षेपदृक्क्षेपवधे] इति । विक्षेपस्य दृक्क्षेपस्य च वधः परस्परमभ्यासः विक्षेपदृक्क्षेपवधः । तस्मिन् पुनस्त्रिज्यया च निहत्य तयोर्विक्षेपदृक्क्षेपयोः कोटयोर्वधेन भक्ते सति यल्लभ्यते तस्य धनुः शशाङ्कादा-वुद्यति सति धनमृणं वा कुर्यात् । तयोर्विक्षेपदृक्क्षेपयोर्हरिदैक्याद् दिशोरेकत्वाद् धनं कुर्यात् । दिग्भेदादृणं च कुर्यात् । शशाङ्कादौ ग्रहेऽस्तं गच्छति सति अन्यथा, हरिदैक्ये ऋणं, तद्भेदे धनं च कुर्यात् ॥ २२ ॥

दृक्क्षेपः काललग्नस्य क्रान्तिरेव खमध्यगे ।
क्रान्तिक्षेपदिशोर्भेदे धनं साम्ये त्वृणं तदा ॥ २३ ॥

एवमुदयास्तमययोर्दृक्कर्मोक्त्वा मध्याह्ने तस्य विशेषमाह— [दृक्क्षेप] इति । खमध्यगे ग्रहेऽप्यनेनैव न्यायेन दर्शनसंस्कारः कर्तुं शक्यः । तत्रायं विशेषः । दृक्क्षेपस्य स्थाने काललग्नस्य क्रान्तिगुण एव ग्राह्यः । काललग्नापक्रमस्य चन्द्रादिविक्षेपस्य च दिशोर्भेदे तदा खमध्यगे ग्रहे दर्शनसंस्कारलिप्ताधनुर्धनं कार्यम् । तयोर्दिक्साम्ये त्वृणं च ॥ २३ ॥

[उदयादिस्थूललग्नं तत्स्फुटीकरणं च]

उदयास्तखमध्येषु लग्नमेवं कृतो ग्रहः ।
मध्यलग्नं स्वकालः स्यात् कृते प्राणकलान्तरे ॥ २४ ॥

सत्रिभो लग्नकालः स्यात् तत्क्रान्तीन्द्वादिभिर्मुहुः ।
मध्यलग्नं तथा कार्यं यावन्निश्चलतामियात् ॥ २५ ॥

(Reduction to Polar longitude : Dṛk-karma)

22. Multiply R sine (of the latitude of the moon etc.) by R sine Zdn and again by R. Divide this by the product of their R cosines (*i.e.*, the product of R cos lat. and R cos Zdn). Find its arc. This should be added to the moon etc. at rise if the latitude and the Zdn are of the same direction, and subtracted, if of different directions. At their setting, the addition and subtraction are to be reversed.

23. When (the moon etc. are) at mid-heaven,[9] the declination of the *Kālalagna* itself is the R sine Zdn. But, in this case, (*i.e.*, in doing the *dṛk-karma* of verse 22, for the moon etc. at mid-heaven), the addition is to be done if the directions of the latitude and the Zdn are different, and subtraction, if they are of the same direction.

(The approximate Orient Ecliptic Points etc. and their Correction)

24 a. The longitude of the planet (*i.e.*, the moon etc.) corrected thus, (*i.e.*, acc. to verses 22, 23) is the respective (approximate) ecliptic point at rising (*i.e.*, Orient), setting (*i.e.*, Occident) and mid-heaven (*i.e.*, meridian) (as the case may be).

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9. By 'mid-heaven' is meant here the meridian.

चरं चोदयलग्नस्य कुर्यात् कालप्रसिद्धये।
अस्त[19]लग्नं सचक्रार्धं प्राग्लग्नं; तस्य कालतः ॥ २६ ॥

चन्द्रदृक्क्षेपलग्नादि[20] नीत्वा तमविशेषयेत्।
रविकालस्य तस्यापि भेदः कालो दिवानिशोः ॥ २७ ॥

दर्शनसंस्कारस्याविशेषं श्लोकचतुष्केणाह— [**उदयास्तखमध्येषु**] इति। तत्र प्रथमं अविशेषहेतुप्रदर्शनार्थं दर्शनसंस्कारमाहाद्यार्धेन। **एवं** दृक्कर्मसंस्कृत**ग्रह उदयास्तखमध्येषु** **तत्तल्लग्नं स्यात्**। एतदुक्तं भवति। स्वोदयकालजे ग्रहे उदयोक्तप्रकारेण दर्शनसंस्कारे कृते स्वोदयकालजं प्राग्लनं स्यात्। स्वमध्याह्ने पुनर्मध्याह्नोक्तप्रकारेण दर्शनसंस्कारे कृते स्वमध्याह्नकालजं मध्यलग्नं स्यात्। स्वास्तमये च तदुक्तप्रकारेण दर्शनसंस्कारे कृते स्वास्तमयकालजमस्तलग्नं स्यादिति। एवं सति इतरेतराश्रयदोषः स्यात्। कुतः? दर्शनसंस्कारेण ग्रहोदयादिकालजं लग्नं ज्ञात्वा नाडिकाकरणेन ग्रहोदयादिकालो वेद्यः। उदयादिकाले विदिते सत्येव चन्द्रादेः स्वोदयकालजत्वमापादयितुं तत्काललग्नदृक्क्षेपलग्नादिकं चानेतुं शक्यम्। तत्सर्वं ज्ञात्वैव दर्शनसंस्कारः कर्तुं शक्य इति। ततो विशेषकर्मणा तत्परिहारः कार्य इति। तत् **'शशाङ्काद्युदयेऽन्यथाऽस्ते'** [कारिका २२, पृष्ठम् १८] इत्यत्रैव सूचितम्।

तत्र **मध्यलग्न**मित्यादिभिस्त्रिभिरर्धैर्मध्यलग्नस्याऽविशेषकर्मोच्यते। **मध्यलग्नं** पृथग्विन्यस्य तद्भुजायाः **प्राणकलान्तरं** गृहीत्वा मध्यलग्ने संस्कुर्यात्। तन्मध्य**कालः स्यात्**। कालात्मकं मध्यलग्नमिति यावत्। स एव मध्यलग्नकालो राशित्रयसहितः **प्राग्लग्नकालः स्यात्**। यदिह काललग्नमिति प्रसिद्धं तत् स्यादित्यर्थः। तत्क्रान्त्या दृक्क्षेपस्थानीयया तत्कालचन्द्रविक्षेपादिभिश्च मध्याह्नोक्तप्रकारेण दृक्कर्म। **मध्यलग्नं मुहुः कार्यम्। यावन्निश्चलतामियात्** अविशिष्टं स्यात् तावत् कार्यमित्यर्थः। एवं मध्याह्नकालस्याविशेषमुक्त्वा उदयास्तमयकालयोरविशेषमाह— **चरं चे**ति। **उदयलग्नस्य** स्वकालसिद्धये **चरं च** संस्कुर्यात्। 'च'कारात् प्राणकलान्तरं च। अस्तमये तु कृतदर्शनसंस्कारो ग्रहोऽस्तलग्नतुल्यो राशिषट्कसहितः **प्राग्लनं** स्यात्। तदपि चरप्राणकलान्तराभ्यां संस्कृतं काललग्नं स्यात्। **तस्य कालतः** प्राग्लग्नकालादेवास्तमयेऽपि दृक्क्षेपादिकं **नीत्वा 'विक्षेपदृक्क्षेप'** इत्यादिश्लोकोक्तप्रकारेण [कारिका २२, पृष्टम् १८] **तं** प्राग्लग्नकालमेवाऽ**विशेषयेत्**। **तस्य** प्राग्लग्नकालस्य **रविकालस्य च** चरप्राणकलान्तरसंस्कृतस्य रवेरपि यो **भेदः** स एव चन्द्रादीनामुदयमध्याह्नास्तमयेषु **दिवानिशोः कालः** स्यात् ॥ २४-२७ ॥

19. C. अस्त frayed out. 20. C. कालादि for लग्नादि

24 b. The Meridian ecliptic point, with its Right ascensional difference applied, is its time, (when corrected).

25. This plus three signs is the *Kālalagna*. Using the declination, moon etc. of this *Kālalagna* time, the Meridian ecliptic point is to be found repeatedly, till there is no difference (between the previous result and the next).

26-27. To the Orient ecliptic point got (in verse 24a), *cara* and also Right ascensional difference are to be applied to get its corresponding time. The Occident ecliptic point got, plus six signs, is its corresponding Orient ecliptic point. From its corresponding time (got by applying its *cara* and Right ascensional difference), the moon, Zdn, the ecliptic point etc. are to be computed, and this Orient ecliptic point time is to be made correct by successive approximation. The difference between this time got and the time of the sun (with the *cara* and the Right ascensional difference applied to it also) is the time of the moon etc. (in their own rising, transiting and setting) day or night.

[छायातः कालानयनम्]

शङ्कुच्छायाकृती युक्त्वा स्वकर्णार्थं पदं नयेत् ।
याम्योदग्भूगुणोनाढ्या द्युज्यान्त्या; विषुवच्छ्रुतेः ॥ २८ ॥

त्रिज्याघ्नायाः स्वकर्णाप्तहीनान्त्या त्रिज्यया हता ।
द्युज्याप्ता चापिता बाणैर्नतप्राणा विधोरमी ॥ २९ ॥

शोध्या[21] मध्याह्नकालात् प्राक्, क्षेप्याः[22] प्रत्यग्गतासुभिः ।
एभिर्विश्लिष्यपूर्वास्तानन्तरप्राणभोगतः ॥ ३० ॥

[23]नीत्वार्केन्द्वादिकं भूयः कुर्यात् कर्मासकृत् तथा ।
साम्यसिद्ध्यै रवीन्दुभ्यां सिद्धयोः कालयोर्द्वयोः ॥ ३१ ॥

एवं चन्द्रस्य उदयमध्याह्नास्तमयकालानयनमुक्त्वा अथ पृच्छकोद्दिष्टैश्छायाङ्गुलैश्चन्द्रनतासूनानीय रात्रिगतगन्तव्यकालानयनं श्लोकचतुष्टयेनाह— [शङ्कुच्छायाकृती] इति । जन्मादिकालच्छायाया अङ्गुल्याद्यात्मिकायाः शङ्कोश्च कृती वर्गौ योजयित्वा तन्मूलीकुर्यात् । किमर्थम् ? स्वकर्णार्थम् । तत्पदं शङ्कुच्छाययोर्भुजाकोट्यात्मिकयोरङ्गुलात्मकः कर्ण इत्यर्थः । अथ याम्यक्रान्तौ तत्क्षितिज्यां स्वाहोरात्रव्यासार्धाच्छोधयेत् । उदग्गोले योजयेत् । एवंभूता द्युज्या अन्त्याख्या ।

अथ विषुवत्कर्णात् त्रिज्याघ्नादत्रानीतेन छायाकर्णेन हृत्वाऽऽप्तम् अन्त्याख्यायास्त्यजेत् । तत्र शिष्टं त्रिज्यया हत्वा स्वाहोरात्रज्यया हृतम् उत्क्रमज्याभिश्चापीकुर्यात् । तच्चापकला विधोर्नतप्राणाः स्युः ।

ते नतप्राणाः प्राक्कपालस्थे चन्द्रे चन्द्रमध्याह्नकालात् मध्यलग्नकालतः शोध्याः । प्रत्यक्कपाले तु क्षेप्याः । अथ एभिर्नतप्राणैः पूर्वं छायावाक्यानीतनतप्राणान् वियोज्य तदन्तरप्राणगतीः पूर्वानीतद्वयोः संस्कृत्य ततो विक्षेपापक्रमादिकं नीत्वा पुनस्तत्सिद्धान्त्यायाः स्वकर्णाप्तहीनायास्त्रिज्याहननादिकं कर्म असकृत् कुर्यात् । कथम् ? तथा, पूर्वोक्तवदेव । किमर्थं तदसकृत् क्रियते ? रवीन्दुभ्यां सिद्धयोः कालयोर्द्वयोः साम्यसिद्ध्यर्थम् ॥ २८-३१ ॥

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21. C. त्याज्या for शोध्या 22. C. क्षेपाः for क्षेप्याः
23. C. नीत्वा चन्द्रार्कं

(The Time from Shadow proper)

28. The square root of the square of the shadow-*plus*-144, is called the Shadow-hypotenuse. The radius of the diurnal circle diminished or increased, by the Earth-sine (got in verse 21), respectively as the declination is south or north, is called *Antyā*.

28b-29. The Equinoctial Shadow-hypotenuse is to be multiplied by R and divided by the Shadow-hypotenuse. This should be subtracted from the *Antyā*, multiplied by R and divided by the radius of the diurnal circle. The arc of this is to be found by using the R versed-sine[10] table. This is the Hour-angle of the moon in *prāṇas*.

30 a. These *prāṇas* are to be subtracted from the time of the mid-day (*i.e.*, the time of the Meridian ecliptic point) if the moon is east of the meridian, and added to, if west.

30b-31. These *prāṇas* are to be subtracted from the time taken at first, (see verse 18). Using the motion during this period to correct the sun, moon etc., the whole operation is to be repeated several times, as before, so that two consecutive times, got by using the sun and the moon, become equal.

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10. If the 'sine' is the bow-string, the 'versine' is like the arrow placed on it. Hence the expression *bāṇaiḥ*.

[24]नीलकण्ठोद्धृतो जातस्तन्त्राब्धेर्न्यायदीधितिः ।
जयत्युद्योतयन् कृत्स्नं प्रभागणितचन्द्रमाः ॥ ३२ ॥

[॥ इति गार्ग्य-केरल-नीलकण्ठसोमयाजि-विरचितं
चन्द्रच्छायागणितम्
समाप्तम् ॥]

24. A. omits this verse and the colophon following.

25. In place of this colophon A reads only श्रीः । श्रीः । श्रीः ।
B. reads समाप्ता चेयम् । C. carries no colophon.

32. Victorious shines, illuminating everything, the 'Moon of Shadow-computation', with its brilliant rays of rules, having been extracted by Nīlakaṇṭha from the ocean of astronomical lore.

[Thus ends

THE COMPUTATIONS CONCERNING MOON'S SHADOW

By

Gārgya-Kerala-Nīlakaṇṭha-Somayāji]

APPENDIX I

इन्दोर्नतप्राणानयनम्

[1]शङ्कुच्छायाकृती युक्त्वा स्वकर्णार्धं पदं नयेत् ।
याम्योदग्भूगुणोनाढ्या द्युज्या स्यादन्त्यसंज्ञिता ॥ १ ॥

गत्यंशत्र्यंशगुणितच्छायाङ्गुलसमन्वितात् ।
व्यासार्धात् पलकर्णघ्नाच्छायाकर्णाङ्गुलोद्धृतम् ॥ २ ॥

अन्त्या तत्फलहीना या विष्कम्भार्धेन ताडिता ।
द्युज्याप्ता चापिता बाणैर्नतप्राणा विधोरमी ॥ ३ ॥

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1. These verses are found in **A,** *i.e.,* Ms. No. 5862-B, in continuation of the Commentary.

APPENDIX I

DERIVATION OF THE HOUR-ANGLE OF THE MOON IN PRĀṆAS

1. The square root of 144-*plus*-the square of the Shadow is called the 'Shadow-hypotenuse'. The radius of the diurnal circle, diminished or increased, respectively, by the Earth-sine (got in verse 21), as the declination is south or north, is called *Antyā*.

2. A third of the moon's daily motion in degrees is to be multiplied by the Shadow in *aṅgulas* and added to R. This should be multiplied by the Equinoctical Shadow-hypotenuse and divided by the Shadow-hypotenuse.

3. The result is to be subtracted from the *Antyā* got above and the product multiplied by R, and divided by the radius of the diurnal circle. The arc of this, using the versed-sine, is the Hour-angle in *prāṇas*.[1]

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1. The three verses here instruct the same thing as given by verses 28-29, with the exception that a correction is made to the first R used in verse 29. This is necessary and does duty for the correction to be made for the sake of the moon's parallax and corresponds to the correction applied in verse 14. See note there.

APPENDIX II

'परमापक्रमकोट्या' इत्यादि-कारिकायाः केरलभाषाविवृतिः ।

परमापक्रमकोटया विक्षेपज्यां निहत्य तत्कोटया ।
इष्टक्रान्ति चोभे त्रिज्याप्ते योगविरहयोग्ये स्तः ॥ १९ ॥

[1]'परमापक्रमकोटचा' एन्नतिन्टॅ वासन । ऑरु वृत्तं वरॅच्चु, पूर्वापर-दक्षिणोत्तररेखकळेयुं वरॅच्चु, पूर्वापररेखयुटॅ वटक्कु परिधिमत्(?) अर्काग्रयोळं नीक्कि ऑरु बिन्दु उण्टाक्कि, पटिञ्ञारु तॅक्केप्पुरत्तुं अत्र नीङ्ङि ऑरु बिन्दु उण्टाक्कि, आ बिन्दुक्कळ् रण्टिन्मेलुं वृत्तकेन्द्रत्तिङ्कलुं कूटि ऑरु रेख उण्टाक्कि, आ रेखक्कु लग्नसममण्डलं एन्नु पेरु । पिन्नॅ दक्षिणोत्तररेखयुटॅ तेक्कुकिषक्कुं वटक्कुपटिञ्ञारुं अर्काग्रान्तरितमायिट्टु ऑरु रेखयॅ उण्टाक्कू । अतु दृक्क्षेपमण्डलम् । पिन्नॅ केन्द्रत्तिङ्कन्नु परक्रान्तियोळं तॅक्कु नीङ्ङि ऑरु बिन्दु उण्टाक्कि लग्नसममण्डलत्तिन्टॅ रण्टु अग्रङ्ङळिलुं इतिङ्कलुं तट्टुमारु ऑरु चापत्तॅ उण्टाक्कू । अतु अपक्रममण्डलम् । पूर्वापररेख घटिकामण्डलम् । दक्षिणोत्तररेखयुटॅ तॅक्कॅ तलय्क्कल् ऑरु ज्यावु उण्टाक्कू । अतु कोटचपक्रमम् । अतिन्टॅ अग्रत्तिङ्कन्नु घटिकान्तमायिट्टु ऑरु ज्यावु उण्टाक्कू । अतु कोटिस्वाहोरात्रम् । कोटिस्वाहोरात्रत्तिन्नु त्रिज्य कर्णम्, अपक्रमत्तिन्नु एतु कर्णम् एन्नु त्रैराशिकम् । तत्फलं दृक्क्षेपम् । दृक्क्षेपकोटियुं विक्षेपकोटियुं उण्टाक्कि 'जीवे परस्परं' चॅय्यू । विक्षेप-दृक्क्षेपङ्ङळॆ तङ्ङळिल् संस्करिच्चाल् ग्रहक्रान्तिकळ् वरुम् । त्रिज्याकर्णत्तिन्नु कोटि स्वाहोरात्रम् ; कोटि इक्कर्णत्तिन्नॅन्तु एन्नु विक्षिप्तक्रान्ति । अविटॅ 'जीवे परस्पर'त्तिङ्कल् रण्टिनेयुं वॅव्वेरॅ हरिप्पू । एन्नाल् अक्कर्णं रण्टु खण्डमायिट्टु वरुम् । त्रिज्यॅक्कु कोटि स्वाहोरात्रम्, कोटि ई खण्डङ्ङळ्क्कु एन्तु एन्नु रण्टु खण्डङ्ङळेयुं वॅव्वेरॅ वरुत्तू । तङ्ङळिल् योगान्तरं क्रान्ति । अविटॅ क्रान्तिखण्डत्तिङ्कल् मून्नु त्रैराशिकम् । नटेत्तेतुं मून्नामतु व्यस्तमाकयाल् तङ्ङळिल् बाधिय्क्कुम् । 'जीवे परस्परं' शेषिक्कि (? क्कुम्) ।

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1. This demonstration, in the Malayalam language, of verse 19 of the *Candracchāyāgaṇita* is found inscribed in Kerala Uni. Ms. 5862-B, in continuation of the text and Sanskrit commentary edited here.

Short 'e' and 'o' which occur in Malayalam are represented in the following passage by ॅ and ॊ, respectively.

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गार्ग्य-केरल-नीलकण्ठसोमयाजि-विरचित-

चन्द्रच्छायागणितान्तर्गत-

श्लोकार्धानाम् अनुक्रमणिका

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